February 2022

CENTRAL ASIA

Socioeconomic Impacts of Road Traffic Injuries in Central Asia

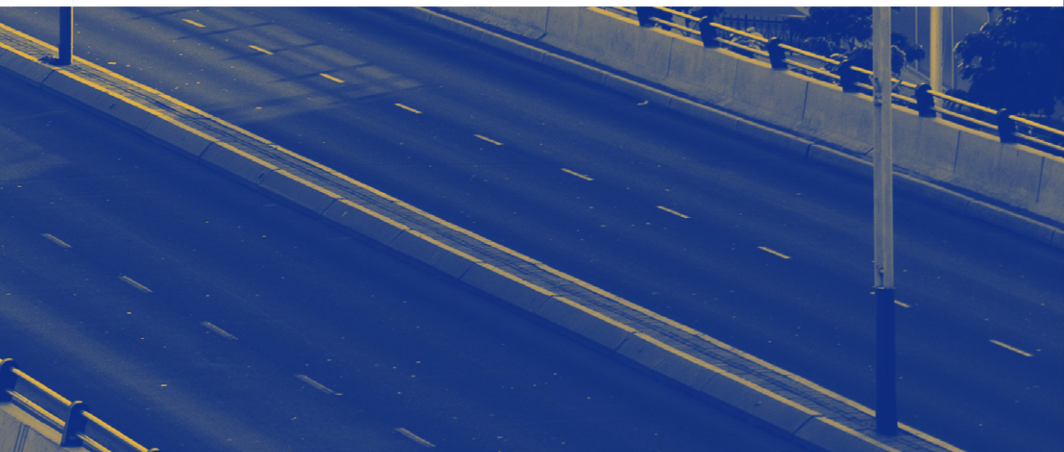
UKaid from the British people

CITA

TotalEnergies FOUNDATION

Bloomberg Philanthropies

WORLD BANK GROUP



GRSF Global Road Safety Facility

© 2022 The World Bank
1818 H Street NW, Washington DC 20433
Telephone: 202-473-1000; Internet: www.worldbank.org

CONTENTS

Acknowledgements viii
About the Authors ix
Abbreviations and Acronyms x
Executive Summary 1
Introduction 4
Chapter 1: Health Care Costs Attributable to Road Traffic Injuries 7
- **Methodology** 8
  - General Approach 8
  - RTI-Related Health Care Consumption 8
  - Road Traffic Crashes 9
  - RTI Cost Valuation Techniques 9
  - Financial Burden of Road Traffic Injuries on Households 9
  - Limitations 10
- **Empirical Results** 10
  - Health Care Costs at a Glance 10
  - Health Care Costs Related to RTC Casualties and Their Impact on Households 12
  - Health Care Costs of Road Traffic Injuries 14
  - Avoidable Costs 17

Chapter 2: The Effect of RTI Mortality and Disability Adjusted Life-Years (DALYs) on Economic Growth 20
- **Data** 22
- **Human Costs** 29
- **Dynamic Macroeconomic Costs of RTI** 32

Chapter 3: Evidence-Based Interventions to Tackle RTIs 35
- **Cost-Effectiveness of RTI Interventions in Low- and Middle-Income Countries** 36
- **Evidence of the Effectiveness of Road Traffic Injury Interventions in Low- and Middle-Income Countries** 40

Chapter 4: Conclusion and Recommendations 44
Appendix A: Selected Road Safety Policies in Four Central Asian Countries 49
Appendix B: Additional Details Regarding Mathematical Formulation of the Model and Data Sources 52

RTI-Related Health Care Consumption 52
Road Traffic Crashes 60
RTI Cost Valuation Techniques 62
Financial Burden of Road Traffic Injuries on Households 67
Target Year 68
Currencies 68

Appendix C: Calculating the Value of Statistical Life, and the Effect of RTI DALYs on Long-Run Economic Growth 69
Value of Statistical Life 69
The Effect of RTI DALYs on Long-Run Economic Growth 69

Appendix D: Road Safety Interventions Implemented in LMICs 77

Bibliography 81

LIST OF FIGURES

Figure 1.1. Health Care Costs of Road Traffic Injuries in Selected Central Asian Countries, 2016

Figure 2.1. RTI and All-Cause DALYs per 100,000 Population

Figure 2.2 RTI and All-Cause Mortality per 100,000 Population

Figure 2.3 RTI DALYs by Age Group

Figure 2.4 RTI Mortality by Age Group

Figure 2.5 RTI DALYs per 100,000 Population, by Region and Income Classification

Figure 2.6 RTI Deaths per 100,000 Population, by Region and Income Classification

Figure 2.7 RTI DALYs and GDP Per Capita

Figure 2.8 RTI Mortality and GDP Per Capita

Figure C1. RTI Mortality

LIST OF TABLES

Table 0.1 Key Road Traffic Indicators in Central Asia and in the Best-Performing Countries in the Europe and Central Asia Region

Table 1.1 Health Care Cost Per Event by Road User, 2016

Table 1.2 Costs by Road User and Type of Care Consumed, 2016

Table 1.3 Health Care Costs by Injury Type (Body Region), 2016

Table 1.4 Health Costs of Road Crash Fatalities, 2016

Table 1.5 Costs by Type of Care Consumed, 2016

Table 1.6 RTI-Related Health Care Costs Avoided in Various Scenarios

Table 2.1. The Value of Statistical Life and the Value of a Statistical Life-Year

Table 2.2. The Effect of Reducing DALYs by 10 Percent

Table 2.3: Benefits of Avoiding a Road Accident (2015-19)

Table 2.4. Macroeconomic Effect of Reducing RTI DALYS in the Working-Age Population by 10 Percent

Table 2.5. Macroeconomic Effect of Reducing RTI Mortality in the Working-Age Population by 10 percent

Table 3.1: Evidence for Cost-Effectiveness of RTI Interventions in LMICs

Table 3.2: Range of Effectiveness of Interventions

Table 3.3 Highly Effective Interventions

Table 3.4: Total Number of Potential Lives Saved Among the Poorest Billion

Table A1: Selected Road Safety Policies in Four Central Asian Countries

Table B1. AIS Injury Distribution for Pedestrians (0-17 years old) in Collision with Cars & Other Light Vehicles, Model Year Pre-2006

Table B2. AIS Injury Distribution for Pedestrians (18-59 years old) in Collision with Cars & Other Light Vehicles, Model Year Pre-2006

Table B3. AIS Injury Distribution for Pedestrians (60+ years old) in Collision with Cars & Other Light Vehicles, Model Year Pre-2006

Table B4. AIS Injury Distribution for Pedestrians (All Ages) in Collision with Heavy Trucks & Buses

Table B5. AIS Injury Distribution for Cyclists (0-17, Non-Helmeted or Unknown) in Collision with Cars & Other Light Vehicles, All Model Years

Table B6. AIS Injury Distribution for Cyclists (18-59, Non-Helmeted or Unknown) in Collision with Cars & Other Light Vehicles, All Model Years

Table B7. AIS Injury Distribution for Cyclists (60+, Non-Helmeted or Unknown) in Collision with Cars & Other Light Vehicles, All Model Years

Table B8. AIS Injury Distribution for Cyclists (All ages, Non-Helmeted or Unknown) in Collision with Heavy Trucks & Buses

Table B9. AIS Injury Distribution for Motorcyclists (18+, Non-Helmeted or Unknown), All Collisions

Table B10. AIS Injury Distribution for Cars & Other Light Vehicles (Drivers 18-59) in Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

Table B11. AIS Injury Distribution for Cars & Other Light Vehicles: (Drivers 60+) in Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

Table B12. AIS Injury Distribution for Cars & Other Light Vehicles (Drivers 18-59) in Non-Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

Table B13. AIS Injury Distribution for Cars & Other Light Vehicles (Drivers 60+) in Non-Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

Table B14. AIS Injury Distribution for Cars & Other Light Vehicles (Occupants 0-17) in All Collisions (Belted and Non-Belted, Model Year Pre-2006)

Table B15. AIS Injury Distribution for Cars & Other Light Vehicles (Occupants 18+) in All Collisions (Belted and Non-Belted, Model Year Pre-2006)

Table B16. Polytrauma Rate in Road User Categories

Table B17.Other Base Estimates for Health Care Consumption and Data Sources

Table B18. Risk of Permanent Medical Impairment on 1%+ and 5%+ levels

Table B19. Country-Reported and Estimated Number of Road Traffic Deaths

Table B20. Country-Reported and Estimated Number of RTC-Injured Casualties

Table B21. Other Base Estimates for Road Traffic Crashes and Data Sources

Table B22. Cost Valuation Techniques by Country

Table B23. Costs of Emergency Medical Services (Standardized for 2016)

Table B24. Costs of Emergency Department Services (Standardized for 2016)

Table B25. Costs of Outpatient Services (Standardized for 2016)

Table B26. Costs of Acute Hospital Services, AIS 1-2 cases (Standardized for 2016)

Table B27. Costs of Acute Hospital Services, AIS 3+ and Polytrauma Cases (Standardized for 2016)

Table B28. Costs of Rehabilitation Services, 1st Stage (Standardized for 2016)

Table B29. Costs of Subacute Hospital and Rehabilitation Services (Standardized for 2016)

Table B30. Total Annual Income per Household in Kyrgyzstan

Table B31. Total Annual Income per Household in Tajikistan

Table B32. Total Annual Income per Household in Kazakhstan

Table B33. Estimated OOP Expenditure per RTC Event in Three Central Asian Countries

Table B34. Local Currency Unit per International Dollar (2016)

Table C1. Summary Statistics

Table C2. The Effect of All-Cause DALYs in the Working-Age Population on Long-Run Economic Growth

Table C3. The Effect of Non-RTI DALYs in the Working-Age Population on

Long-Run Economic Growth

Table C4. The Effect of All-Cause Mortality in the Working-Age Population on Long-Run Economic Growth

Table C5. The Effect of All-Cause Mortality in the Working-Age Population on Long-Run Economic Growth

Table D1: Examples of Proven and Promising Road Safety Interventions Implemented in LMICs

Table D2: Single Interventions for Specific Unintentional Injuries

Table D3: Packages of Unintentional Injury Interventions

BOXES

Box 0.1: Selected Road Safety Policies in Four Central Asian Countries

ACKNOWLEDGEMENTS

This study was conducted by a World Bank team led by Haileyesus Adamtei, Senior Transport Specialist, Transport Global Practice of the Infrastructure Practice Group, and Elvira Anadolu, Senior Health Specialist, Health, Nutrition, and Population Global Practice. It included the following team members: Irina Li, Transport Specialist; Marc Suhrcke, Lorenzo Rocco, and Andrei Mecineanu (consultants and authors of the report); and Arystan Massanov, Jamshid Sodikov, Erkin Checheibaev, and Nizom Salimov (consultants).

The study was financed by the Global Road Safety Facility.

The team is grateful to the following professionals for peer-reviewing this work at various stages of the preparation: Said Dahdah, Lead Transport Specialist; Dipan Bose, Senior Transport Specialist; Driss M. Zine-Eddine El-Idrissi, Lead Health Economist; Nijat Valiyev, Senior Infrastructure Specialist; and Antonio Giuffrida, Program Leader.

The team would also like to express its gratitude for the overall management and guidance extended to the team by Karla Gonzalez, Transport Practice Manager for Europe and Central Asia; Tania Dmytraczenko, Health, Nutrition, and Population Practice Manager for Europe and Central Asia; and Sascha Djumena, Country Program Coordinator for Europe and Central Asia.

The team would also like to recognize the support provided by the World Bank Country Management teams of Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan throughout the course of the study.

Many government offices in the four countries studied contributed invaluable data, general information, and support for this work. The support and insight provided by many members of the following organizations is gratefully acknowledged and appreciated.

Kazakhstan: Ministry of Internal Affairs, Ministry of Health, Ministry of Industry and Infrastructure Development.

Kyrgyzstan: Ministry of Economy, Ministry of Health, National Statistical Committee, Mandatory Health and Insurance Fund, Minister Government Office, State Registration Office.

Tajikistan: Ministry of Internal Affairs, Ministry of Health and Social Protection, Agency on Statistics under the President.

Uzbekistan: Ministry of Investments and Foreign Trade, Ministry of Health, Ministry of Transport.

While every effort has been made to use the most recent and trustworthy data, the World Bank does not guarantee the accuracy of the data used in this report. This is not a full or independent evaluation. It was prepared in a relatively brief period of time, and the impact of the COVID-19 pandemic created additional constraints for additional data collection and comprehensive discussions with the governments involved.

ABOUT THE AUTHORS

Marc Suhrcke is a Professor of Global Health Economics at the Centre for Health Economics at the University of York, and he heads the research program on "Health and Health Systems" at the Luxembourg Institute of Socio-Economic Research (LISER). Previously, he was Professor of Public Health Economics at the University of East Anglia, and he has held research positions with the World Health Organization (WHO); UNICEF's Innocenti Research Centre; the University of Hamburg; the European Bank for Reconstruction and Development; the Centre for European Policy Studies; the European Commission; and the Hamburg Institute for International Economics. His research revolves around a wide range of health economic aspects, including the socioeconomic determinants and consequences of health and health inequalities, as well as evaluation of the impact of population- and system-level policies on health and related outcomes. His research has been funded by the World Bank, WHO, the European Commission, Department for International Development, the Department of Health (England), the Global Fund to Fight AIDS, Tuberculosis and Malaria, the European Centre for Disease Prevention and Control, the National Institute for Health Research, the Medical Research Council, the Economic and Social Research Council, the Gates Foundation, and the Newton Fund, among other organizations.

Lorenzo Rocco is Professor of Economic Policy with the University of Padova. He is an applied economist, with interests in health economics and the economics of education. His research has been published in the *Journal of Economic Growth*, the *Journal of Public Economics*, and the *Economic Journal*, among other publications.

Andrei Mecineanu received his PhD and MPH degrees in Healthcare Management and Public Health in 2012 and 2015 from the State Medical and Pharmaceutical University, Moldova. From 2012 to 2016 he was an affiliated researcher and lecturer at the School of Management in Public Health, Moldova. Since then, he has been an international consultant for the World Bank, WHO, the United Nations Development Programme, and other agencies. His research and teaching interests include health system performance, and health policy and systems research.

ABBREVIATIONS AND ACRONYMS

AIS	Abbreviated Injury Scale
ALS	Advanced Life Support
BCR	Benefit Cost Ratio
BLS	Basic Life Support
BS	Budget Share
CAREC	Central Asia Regional Economic Cooperation
CHE	Current Health Expenditure
COI	Cost of Illness
DALY	Disability Adjusted Life-Years
DCP3	Disease Control Priorities 3
DRG	Diagnosis-Related Group
ECA	Europe and Central Asia
ED	Emergency Department
EMS	Emergency Medical Service
FFS	Fee for Service
FR	First Responder
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GEM	General Equivalency Mapping
GHDX	Global Health Data Exchange
GLS	Graduated Licensing Scheme
GNI	Gross National Income
HALE	Health-Adjusted Life Expectancy
HIC	High-Income Country
HSA	Hospital Stay for Acute Care
HSAR	Hospital Sub-Acute and Rehabilitative Care
ICD	International Classification of Diseases
ICDPIC-R	International Classification of Diseases Programs for Injury Categorization
ICER	Increment Cost-Efficiency Ratio

IHME	Institute of Health Metrics
IHRA	International Harmonization Research Activities
ILS	Intermediate Life Support
INRETS	French National Institute for Transport and Safety Research
Int$	International Dollar
IRCOBI	International Research Council on Biomechanics of Injury
ISS	Injury Severity Score
LCU	Local Currency Unit
LMIC	Low- and Middle-Income Countries
LV	Light Vehicle
MAS	Medical Aid Scheme
MY	Model Year
NPV	Net Present Value
NHTSA	National Highway Traffic Safety Administration
OLS	Ordinary Least Squares
OOP	Out of Pocket
OSAR	Outpatient Sub-Acute and Rehabilitative Care
PMI	Permanent Medical Impairment
PPP	Purchasing Power Parity
PWT10.0	Penn World Table version 10.0
RPMI	Risk of Permanent Medical Impairment
RTC	Road Traffic Crash
RTI	Road Traffic Injury
SBT	Selective Breath Testing
SDG	Sustainable Development Goals
TC	Treatment Course (episode of care)
UMI	Upper and Middle-Income
VSL	Value of Statistical Life
VSLY	Value of Statistical Life-Year
WHO	World Health Organization
WISQARS	Web-Based Injury Statistics Query and Reporting System
WTP	Willingness to Pay
WVS	World Values Survey
2SLS	Two-Stage Least Squares
Int$	International dollars
$	US dollars

“

The cost estimates discussed in this report indicate the potential for significant economic cost savings if both deaths and injuries from road crashes could be substantially reduced in these countries.

EXECUTIVE SUMMARY

Road traffic injuries (RTIs) are well known to cause enormous human suffering in terms of both morbidity and mortality, and on a global scale. The economic dimension of the disease burden is far less well understood; but it is important to assess the size of the economic burden so that it can be considered when calculating the cost-benefit ratio of policies to tackle this problem. Because it is, in principle, and to some degree, an avoidable one.

This report focuses primarily on assessing various dimensions of the economic consequences of RTIs, as applied specifically to four Central Asian countries (Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan) – a part of the world in which there is still a major need to reduce RTIs.

Chapter 1 presents various dimensions of the **health care costs** attributable to RTIs, both at the health system and at the individual/household levels. This study shows that on top of the harm RTIs inflict upon human health, they also impose a **considerable financial burden on health care systems**. In 2016, the total estimated health costs of RTIs in these four countries was approximately Int$95 million, ranging from Int$2.8 million in Tajikistan to Int$49.3 million in Kazakhstan. In Kazakhstan, the overall health costs resulting from RTIs were similar to the cumulative expenditure for rehabilitative and palliative care within the state-guaranteed basic package. In Kyrgyzstan, they exceeded the expenditures for emergency medical services within the mandatory health insurance fund; and in Tajikistan, they exceeded the expenditures for ambulatory care within the national budget.[1]

These costs were mainly driven by the types of injuries that result from road crashes, and by permanent medical impairment. For all injury and health care types, the cost per event that is generated by pedestrians was the highest in all four countries. However, motorized four-wheel users made up the largest group in absolute numbers of affected people. Serious injuries and injuries to multiple body regions accounted for only a small share of acute inpatient cases, but constituted the largest share of aggregate hospital costs in most of these countries. At the same time, slight injuries contributed to nearly 40 percent of the cases of permanent medical impairments in these four countries. This corresponded to Int$13.2 million as costs for long-term care, ranging from Int$0.37 million in Tajikistan to Int$7.24 million in Kazakhstan.

The heavy financial burden on health care systems to manage RTIs in these countries adds weight to the urgency to increase preventive efforts by road safety policymakers, and should motivate appropriate organization of the post-crash response by health care system decision makers. The cost estimates discussed in this report **indicate the potential for significant economic cost savings if both deaths and injuries from road crashes could be substantially reduced in these countries**.

1 The weighted mean cost per road traffic crash (RTC) casualty was estimated at Int$1,166 in Kazakhstan (the equivalent of 4.7 percent of GDP *per capita*); Int$453 in Kyrgyzstan (9.7 percent of GDP *per capita*); Int$1,211 in Uzbekistan (18.8 percent of GDP *per capita*); and Int$674 in Tajikistan (21.8 percent of GDP *per capita*).

Chapter 1 also provides an analysis of the likely health cost savings, conditional on three RTI reduction scenarios.

Chapter 2 takes a more macro-level perspective, by estimating the RTI-attributable **human costs** (using a "value-of-statistical-life" (VSL) approach) as well as the effect of RTIs on **economic growth** in these four countries. Human costs – also sometimes referred to as "welfare costs"– generally account for the largest cost component in analyses carried out both in rich and poor countries (Wijnen & Stipdonk, 2016).

One previously overlooked dimension of the economic burden of RTI corresponds to the effect of RTIs on economic growth. The loss of human capital and the reduced life expectancy due to RTI mortality dynamically alter the functioning and performance of the entire economy through their effects on the labor and goods markets. These effects are accounted for in this report by estimating the impact of RTI mortality and morbidity on the long-run growth rate of per capita GDP.

The results presented in this study show that permanently reducing RTI-attributable DALYs in the working-age population by 10 percent would save human costs by an amount equivalent to a significant fraction of the 2019 GDP of these countries, ranging from 2.7 percent in Tajikistan to 6.4 in Kazakhstan. The effect of RTIs on the prospects for the economic development of the countries is almost as large: the same hypothetical reduction in RTI-attributable DALYs would significantly enhance economic growth: by 2048 per capita GDP would be expected to be Int$140 higher in Kazakhstan than it would be if RTI DALYs had remained unchanged; in Kyrgyzstan Int$32.3 higher; in Tajikistan Int$11.0 higher; and in Uzbekistan Int$55.4 higher. This implies a total additional income ranging from 2.7 percent of 2019 GDP in Tajikistan to 5.5 percent in Kyrgyzstan. These are relatively large numbers which add to the estimated value-for-money of policies to tackle RTIs.

In principle, RTIs are preventable and so are their economic costs. Around the world, there are policies that have proven to be effective in reducing the number of road accidents, as is discussed in **Chapter 3.** However, in order to decide whether a particular policy intervention is cost-effective, and justifiable from an economic efficiency perspective, it is necessary to have detailed information on 1) the costs of the intervention; 2) its effectiveness in reducing road traffic fatalities and injuries; and 3) the economic benefit of a life-year saved. With this information at hand, it is possible to judge whether the cost of one life-year saved by means of a given policy is smaller than its benefit, and which policy option out of those available has the larger return per dollar invested.

This report contributes to the third question above, while the first two remain outside its scope. Further research and a consistent effort of primary data collection is necessary in order to address these questions, because the cost and the effectiveness of each policy depends on the specific context in which it is to be implemented. Nevertheless, the evidence produced in this report about the magnitude of the benefits of reducing RTI shows that investing in road safety offers great potential for economic cost savings, and suggests that several policy interventions, and/or combinations of interventions, are at the very least likely to represent good "value-for-money."

Currently, most of the road safety interventions undertaken by the health care systems are focused on the post-impact stage and are aimed at preventing death and reducing the severity of injuries once an accident has occurred. The results of our study indicate a need for preventive measures and policy interventions across the "chain of opportunities," including through emergency rescue, prompt access to emergency and trauma care, and rehabilitation. Achieving this will require more information on the quality and organization of post-crash care services in these countries; there is also scope for improving data systems across the transport, health care, and police sectors to better enable future quantitative evaluations that can inform system reform. The recording and reporting of injury-related data various phases of post-crash care are essential to identifying priority areas, monitoring progress, and evaluating whether resource allocation is being appropriately directed; for example, into the monitoring of emergency medical services (EMS) and/or hospital injury surveillance.

The emphasis in health care system responses to RTIs should be on the provision of timely and coordinated assistance to people with RTIs on site (prehospital care) as well as in the hospital, by assuring the availability of: (1) qualified personnel among those who are first to reach the scene (paramedics, doctors, first aid-trained police and fire brigades); (2) transport (ambulances with required equipment, helicopters); (3) hospitals with emergency departments situated near major roads, and (4) highly qualified medical personnel and medical technology in hospitals to treat severe cases with polytrauma.

There is no shortage of general recommendations on key policies that are widely seen to represent an effective response for reducing the burden of RTIs. As far as the *prevention* of RTIs is concerned, those recommendations include:

- Reduction of risk exposure by stabilizing motorization levels, providing alternative modes of travel, and improving land-use planning practices;
- Reduction of risk factors directly related to crash causation, such as speeding, drinking and driving, using unsafe vehicles on unsafe roads (with inadequate safety features for the traffic mix), and failing to enforce road safety laws effectively;
- Reduction of the severity of injuries by mandating and enforcing the use of seat belts, child restraints, and helmets, as well as by improving road infrastructure and vehicle design to protect all road users.

Ideally, these and other policies should be considered as part of a holistic approach to tackling the RTI burden, within the context of a "Safe System," taking into account each of the Safe System pillars (Road Safety Management; Safe Roads; Safe Speeds; Safe Vehicles; Safe Road Users; and Post-Crash Care), and recognizing that evidence-based solutions should be adopted from across these pillars to produce effective road safety outcomes.

Notwithstanding a broad international consensus in this set of policies, there remains a lack of context-specific evidence from RTI policies in a low- to middle-income country (LMIC) context in general, and for these four Central Asian countries specifically. This applies to both the evidence of effectiveness, but – not surprisingly – even more so to the evidence of cost-effectiveness, which would be particularly useful for priority-setting purposes.

In the scarce literature that does exist on RTIs in LMICs, there are nonetheless some encouraging findings about the "return on investment" of a *set* of RTI interventions, with some polices possibly even paying for themselves through the savings they produce in terms of health care cost avoidance and other potential economic savings. This includes three interventions that are relevant to all road users – speed enforcement, alcohol enforcement, and safer road infrastructure – and three additional interventions that are relevant for particular groups—enforcing helmet use for motorcycle riders; enforcing seat belt use for occupants of motor vehicles; and setting up graduated licensing schemes for young drivers.

Future research should seek to fill this evidence gap; better contextualize the existing global evidence base; and increase the chances for take-up by national and regional policymakers in LMICs generally, and in Central Asia in particular. Such research will depend on the production, availability, and analysis of appropriate data – a clear challenge, and not only in the four Central Asian countries studied here.

INTRODUCTION

Road traffic accidents impose a major – and at least in principle avoidable – global health burden. Worldwide, road traffic deaths have been rising steadily, from 1.15 million in 2000 to 1.35 million in 2018. Road traffic injuries (RTIs) are the single largest cause of mortality and long-term disability among young people aged 15-29, and their impact is also considerable among the working-age population more broadly. Therefore, they can be expected to pose a substantial burden on the limited health care systems and societal resources in low-to-middle-income countries (LMICs), where the global burden of RTIs is currently concentrated, following sharp declines in high-income countries in recent decades. LMICs suffer 90 percent of global road deaths, despite accounting for only 50 percent of the vehicles (WHO 2018).

Every traffic crash causes human harm. When death or serious injury results, this loss is compounded by the harm to whole households and social networks. Since many RTIs involve the adult breadwinners of families, there are often also adverse effects on their children, who may need to drop out of school or university and start working to support their families.

The challenge has not gone unnoticed at either the national or the international level. For instance, in 2011, the United Nations released the Global Plan for the Decade of Action for Road Safety (2011–2020). In 2015, RTI prevention also became part of the Sustainable Development Goals (SDGs) as Target 3.6: to cut in half by 2020 the number of *global deaths and injuries from road traffic accidents*).[2]

In Central Asia and some of its neighboring countries, the Central Asia Regional Economic Cooperation (CAREC)[3] Program has also developed a regional road safety strategy, with the objective of reducing fatalities on CAREC road corridors by 50 percent by 2030 as compared to 2010, by making CAREC international road corridors "safe, efficient and attractive for all road users."

Despite such high-level recognition of the problem and commitment to various strategies and plans, actual progress in reducing road traffic fatalities and injuries has been slow. While many countries have made significant strides toward reducing RTIs, more progress could have been made; and the prevalence of RTIs and the associated harm remain unnecessarily high in many countries, in particular in the Central Asian countries.[4]

This report seeks to highlight the case for action, by documenting the situation in four Central Asian countries on selected dimensions of the economic costs associated with road traffic injuries (RTIs), and–conversely – the economic benefits that could be reaped from substantively reducing them. The focus is in particular on the costs in terms of health care, macroeconomic growth, and human (or "welfare") costs.

---

2 Road traffic is also captured in SDG target 11.2: "...by 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, people with disabilities and older people."

3 CAREC is a program that was established in 1997 by the Asian Development Bank to encourage economic cooperation among countries in Central Asia and nearby parts of Transcaucasia and South Asia. The 11 members of CAREC are Afghanistan, Azerbaijan, the People's Republic of China, Georgia, Kazakhstan, the Kyrgyz Republic, Mongolia, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan.

4 See Table 0.1 for statistics on the two best-performing countries in the Europe and Central Asia region; Box 0.1 for a summary of the state of some key road safety policies in these countries; and Appendix A Table A1 for further details.

This report is structured into three main chapters. **Chapter 1** estimates various dimensions of the health care costs attributable to RTIs, both at the societal and individual/household levels. **Chapter 2** takes a macro-level perspective, first, by estimating the economic consequences of RTIs in terms of their impact on national per capita incomes, and, second, by estimating the broader human costs of RTIs (or the benefits of reducing RTIs), building on the Value-of-Statistical Life approach. While the evidence on the cost burden alone may be helpful in underlining the urgency of the problem, evidence-based decision making in this domain will ideally require indications on what can and should be done to reduce RTIs, and data on what it will cost. **Chapter 3** provides a brief synthesis of the existing evidence base relating to the effectiveness and cost-effectiveness of RTI interventions in LMICs, as input into further specific analysis of recommended policy responses for each of the Central Asian countries studied here. **Chapter 4** provides a conclusion, and suggests some preliminary recommendations.

BOX 0.1: Selected Road Safety Policies in Four Central Asian Countries

The World Bank has recently undertaken a major global exercise to take stock of key elements of road safety policies in lower- and middle-income countries (LMICs), including in the four countries studied in this report (World Bank 2019). While there is no claim to the completeness of the information, and while policies may well have evolved since this assessment, Appendix A Table A1 summarizes key elements of the policies that were reviewed. A brief overall assessment across four selected domains highlights these facts:

- ***Speeding is a major risk factor for road crash injuries, contributing to both crash risk and crash consequences.*** Effective speed management measures, such as establishing and enforcing speed limit laws, traffic calming through roadway design and other measures, and vehicle technology need to be widely implemented. While all four countries have a national speed limit law, the limits vary, and in some of the countries should be further reduced.
- ***Universal deployment of improved vehicle safety technologies for both passive and active safety through a combination of harmonization of relevant global standards, consumer information schemes, and incentives to accelerate the uptake of new technologies would reduce RTIs significantly.*** Thus far, out of the available menu of speed-calming options, all four countries have resorted only to vertical deflections (traffic-calming measures that create a change in the height of the roadway).
- ***Establishing and enforcing laws to address the major behavioral risk factors for RTIs – drink- driving; nonuse of helmets, seat belts, or child restraints; and speeding – should be among these countries' priorities.*** However, there remains variation across the four countries; for example, the extent of seat belt law enforcement appears to be limited in some of the countries.
- ***Good post-crash care reduces deaths and disability and suffering for road crash survivors.*** An effective emergency medical care system and processes plays a key role here. While all four countries have national emergency numbers for people to call, not all have a trauma registry system, and there is variation in general health system performance aspects.

Table 0.1: Key Road Traffic Indicators in Central Asia and in the Best-Performing Countries in the Europe and Central Asia (ECA) Region

	2016 WHO ESTIMATED ROAD FATALITIES	2016 GBD ESTIMATED ROAD FATALITIES	2016 WHO ESTIMATED FATALITY RATE/ 100,000 POP.	2016 GBD ESTIMATED FATALITY RATE/ 100,000 POP.	% TREND IN FATALITY RATE/ 100,000 (2013 - 2016)	MOTORIZATION REGISTERED VEHICLES/ 100,000 POPULATION	% OF ROAD CRASH FATALITIES AND INJURIES IN THE ECONOMICALLY PRODUCTIVE AGE GROUPS (15 - 64 YEARS)
Kazakhstan	3,158	2,780	17.6	15.7	-17.5%	24,367	82%
Kyrgyzstan	916	901	15.4	14.4	-17.6%	17,272	84%
Tajikistan	1,577	648	18.1	7.2	10.4%	5,037	82%
Uzbekistan	3,617	4,015	11.5	12.6	-6.1%	0	84%
BEST -PERFORMING COUNTRIES IN THE REGION							
Macedonia	134	164	6.4	7.5	5.8%	21,284	73%
Serbia	649	797	7.4	8.9	-6.1%	25,877	65%

Source: World Bank (2019). "Guide for Road Safety Opportunities and Challenges: Low- and Middle-Income Country Profiles." Washington, DC: World Bank.

Note: The table uses two sources for the estimation of the road fatalities: the World Health Organization (WHO), and the Global Burden of Disease project of the Institute of Health Metrics (GBD)

CHAPTER 1:
HEALTH CARE COSTS ATTRIBUTABLE TO ROAD TRAFFIC INJURIES

The health care costs of road traffic crashes (RTCs), and their evolution over time is a function of the size of the injury burden (incidence, prevalence, mortality); the progress in protective vehicle technology; and improved safety of road infrastructure. Road traffic deaths and serious injuries are in principle preventable since the risk of incurring injury in a crash is largely predictable; and proven, effective interventions do exist.[5] In this sense, road traffic injuries (RTIs) share similar characteristics with other prominent and preventable conditions, including heart disease, cancer, and stroke (Bolen et al. 1997). In the context of RTIs, the main role of the health care system is in the post-impact stage, and is aimed at preventing death as well as reducing the severity and consequences of injuries once an RTC has occurred. By contrast, interventions to *prevent* crashes fall outside of the health care system. Assessing the health care costs of RTIs may serve as an important input into the debate about road safety in Central Asia, and unit cost values--that is, the value of an injury by type or costs--are key factors to consider in policy development and cost-benefit analyses for safety programs and the design of post-crash trauma care systems. In addition, just as with burden of disease metrics, cost estimates can be compared between several types of injury that differ with respect to severity and type of care needed (Meerding 2004; Segui-Gomez 2003).

Estimates of the health care costs of RTIs are relatively scarce as compared to the typically more frequently assessed costs of property damage or production loss. Nonetheless these costs can be expected to impose a significant cost burden from the perspective of individuals, households, and the health sector overall. Assessing the impact of RTIs on the financial burden faced by affected households is challenging, because some of the burden of care may be borne by others--for example, subsidized public facilities--or may be deferred into the future, as households with members who have been injured in crashes incur debt or are forced to sell their assets in order to pay for care, or household members experience earning losses (Gertler and Gruber 2002).

This chapter will contribute to filling the evidence gap of estimating the economic costs of RTIs, applied to the health care systems in these four countries, by highlighting the total health care costs; costs by type of care; and costs by type of injury. It will also discuss the estimated health care costs that could be avoided by implementing suitable road safety policies. Finally, an estimation of the health care cost burden of RTIs on households at the lower end of the income distribution will be considered.

---

5 The risk of impairment and long-term consequences (and hence the health care treatment cost burden) does of course increase as a function of the severity of injuries; however, the vast majority of nonfatal injuries leading to medical impairment are slight rather than serious (Malm et al. 2008; Bohman et al. 2014; Gustafsson et al. 2015).

The results presented in this chapter provide the first detailed quantification of the health care costs attributable to RTIs, as well as their distribution, in four Central Asian countries. They therefore offer information that can help road safety and health care policymakers design a comprehensive approach to tackling the problems created by road traffic crashes.

METHODOLOGY

General Approach

This study uses the cost-of-illness (COI) approach, where health care costs are the product of major parameters of the cost model – incidence, care volume, consumption rate, and unit costs. The method used for each of these parameters is discussed in the sections below, and in greater detail in Appendix B. The method chosen for each of these parameters took into account (1) the lack of injury surveillance systems and/or the nature of available data to explore patterns of injury severity; and (2) the heterogeneity of available data on health care consumption pertaining to these four countries.

Costs were estimated from a health system perspective, which means that all medical costs were included, regardless of the source of payment (individual, household, government, third-party payers, etc.). Overall health care costs were estimated for the RTCs that occurred in the target year, 2016. The costs were standardized in the national currency of each country to enable comparing the economic parameters from various years to the prices in the target year, by using the consumer price index retrieved from the World Bank database.[6] Following standard practice, and again to enable comparison from country to country, all costs were converted to international dollars (Int$),[7] using the purchasing power parity (PPP) conversion factors from 2016.

RTI-Related Health Care Consumption

This study uses an approach based on health care consumption groups, to comprehensively reflect the severity of clinical injuries and the care consumed. All injured casualties were allocated to economically homogeneous patient groups that were predictive in terms of health care consumption. The groups were defined based on the combination of injured body region and severity of injury, using the Abbreviated Injury Scale (AIS).[8]

Since reliable and accurate metrics to define country-specific injury patterns were not available for these countries, the clinical injury outcome distribution was modeled by applying mappings that relate external cause to the nature of injuries, using a tool called E-N mappings, which is based on the structural models of injury causation (Bhalla et al. 2011). This approach has previously been recommended by the World Bank Global Road Safety Facility (GRSF) in cases where the incidence of injury outcomes cannot be directly estimated (Bhalla et al. 2011). Such models recognize that the distribution of injury outcomes is a function of the crash characteristics along with the biological characteristics of the injured person.

6 https://databank.worldbank.org/home.aspx

7 The International Dollar is the unit of currency that has the same purchasing power parity (PPP) as the US Dollar at a given point of time. It reflects the country's currency exchange and PPP rates for a specific year, and is used to compare the prices of goods and services between countries and over time; that is, it shows how much a local currency unit is worth within the country's borders, and the comparable amount of goods and services it would buy in another country.

8 https://www.aaam.org/abbreviated-injury-scale-ais/

In this study, E-N mappings developed from in-depth crash databases, trauma registers, hospital information systems and linked police-hospital databases were used for the extrapolation. AIS injury rates were attributed to patient groups considering the following potential contributory factors: crash characteristics - collision configuration, crash opponents, vehicle body type, vehicle model year, occupant position, seat belt and helmet use status; and casualty biological characteristics such as age, which reflects anthropometric and biomechanical load limits. More detailed information regarding the injury outcome distribution, including AIS injury rates, is presented in Appendix B (Tables B1 – B15). Patients with an AIS of 3 or above (AIS3+) were considered to be seriously clinically injured (Perez et al. 2016). Considering that the maximum AIS score is not sensitive to polytrauma (injuries to multiple body regions), input values derived from research on crash scenarios were applied.

Road Traffic Crashes

This analysis takes into account the existence of bias in reporting RTC data--for example, discrepancies in police-reported and hospital-reported data--since the underreporting of road accidents exists in all countries (WHO 2018). The country-reported RTC data were corrected for underreporting and adjusted for various parameters that are used to define RTC-related terms at country-level regulations in order to approximate the real magnitude of RTCs (Appendix B, Tables B19 and B20). The estimated number of road traffic deaths was based on the World Health Organization (WHO)-generated estimates of road traffic deaths for all member states, while the estimated number of injured road traffic users was calculated by applying correction factors developed by the EU-funded HEATCO research project (WHO 2018; Bickel et al. 2006).[9] Other RTC-related data, such as vehicle fleet composition, registered vehicles by model year, and the like were obtained from national statistical organizations and public authorities with responsibilities in the area of road safety (Ministries of Internal Affairs, Ministries of Transport, etc.).

RTI Cost Valuation Techniques

RTI-related health care costs by category were valued using either restitution costs or top-down micro-costing methods. Top-down micro-costing was applied whenever formally approved tariffs were not in place, or they did not reflect the real costs of delivered care. Tariffs approved or established according to the methodology approved by the Ministries of Health were used in the calculations. (See Appendix B, Tables B23 – B29).

Financial Burden of Road Traffic Injuries on Households

The choice of the method used to assess the financial burden of RTIs on households, as in the case of the major parameters of the cost model, was mainly constrained by the limited and heterogeneous availability of data. The budget share (BS) approach was used to estimate the financial burden on households in the lowest income group. The estimated financial burden index refers to health care costs that are attributable to RTIs, expressed as a percentage of household income and in relationship to a predefined (threshold) limit. In alignment with the literature in this field, the threshold of 10 percent of average household income was applied (Russell 1996; Russell 2004). The financial burden index represents an average figure. It does not reflect either the way that *all* households experience health care costs, or the full landscape of such costs. However, increases in the financial burden suggest that poorer households will

9 The HEATCO acronym stands for Developing Harmonised European Approaches for Transport Costing and Project Assessment. HEATCO's primary objective was the development of harmonized guidelines for project assessment and transport costing on the EU level. This included the provision of a consistent framework for monetary valuation based on the principles of welfare economics.

be particularly adversely affected, with a higher percentage of their income becoming devoted to out-of-pocket payments and thus not available for other needs.

The BS approach requires only limited data, but it does not capture the situation of poor households specifically. In order to appropriately assess the burden of health care costs related to RTIs on household economic outcomes, country-specific, individual-level data will be required so that catastrophic health care expenditures and medical impoverishment in terms of poverty headcount and the poverty gap can be calculated. However, such survey-based data were not available for these four countries.

Limitations

The cost model has several limitations, as discussed below and in further depth in Appendix B. First of all, the analysis presented here relies on E-N mappings to model the RTI outcomes distribution, since reliable and accurate metrics to define country-specific injury patterns were not available for these four countries. This could result in either underestimating or overestimating the country-specific health care cost of RTIs. Second, because data related to care consumption by crash casualties are missing, it was necessary to apply conservative assumptions and/or normative judgments/policy targets within the health care system. This will have increased the probability that the total health care costs are underestimated rather than overestimated. Third, two of the countries, Uzbekistan and Tajikistan, did not apply a base rate or relative cost weights in their tariff estimations, which would have allowed the calculation of budget-neutral tariffs. The cost per case/episode of care essentially functions as a bundled fee-for-service (FFS) mechanism. This could cause overestimation of the costs for specific categories. However, overall, these limitations do not substantially compromise the results of the study, which has many strengths and is a first step in understanding the economic costs of RTIs on Central Asian health care systems.

EMPIRICAL RESULTS

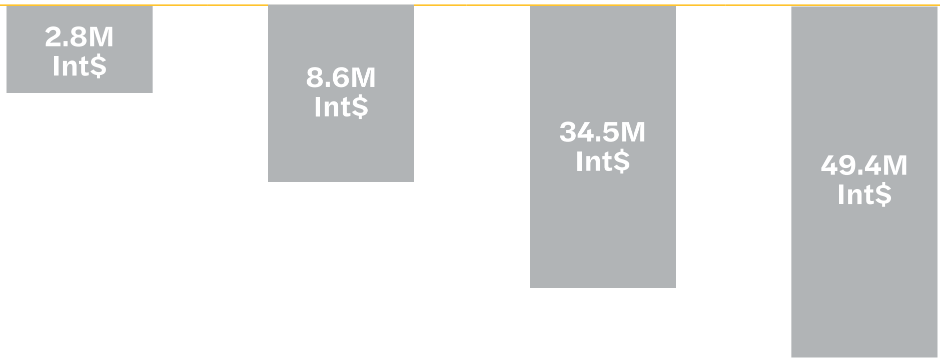
Health Care Costs at a Glance

The total health care costs of the estimated RTIs that occurred in 2016 in the four countries amounted to Int$95 million, ranging from Int$2.8 million in Tajikistan to Int$49.3 million in Kazakhstan. This corresponded to 0.34 percent of current health expenditure (CHE) in Kazakhstan, 0.47 percent in Kyrgyzstan, 0.34 percent in Uzbekistan, and 0.15 percent in Tajikistan (Figure 1.1).

Uzbekistan and Kazakhstan generated health care costs per road traffic casualty three times higher than Kyrgyzstan, and nearly twice as much as Tajikistan. These differences are strongly related to differences in economic development (GDP per capita) and health care expenditure, as well as in the institutional designs of health care delivery.

Figure 1.1. Health Care Costs of Road Traffic Injuries in Selected Central Asian Countries, 2016

TAJIKISTAN	KYRGYZSTAN	UZBEKISTAN	KAZAKHSTAN
Int$ 674 Health cost per RTC casuality	**Int$ 453** Health cost per RTC casuality	**Int$ 1,211** Health cost per RTC casuality	**Int$ 1,116** Health cost per RTC casuality
0.15% Total cost (% of CHE)	**0.47%** Total cost (% of CHE)	**0.34%** Total cost (% of CHE)	**0.34%** Total cost (% of CHE)
320% Health cost per RTC casuality (% of CHE per capita)	**198%** Health cost per RTC casuality (% of CHE per capita)	**312%** Health cost per RTC casuality (% of CHE per capita)	**129%** Health cost per RTC casuality (% of CHE per capita)
21.8% Health cost per RTC casuality (% of CHE per capita)	**9.7%** Health cost per RTC casuality (% of CHE per capita)	**18.8%** Health cost per RTC casuality (% of CHE per capita)	**4.7%** Health cost per RTC casuality (% of CHE per capita)
Total Health Costs of RTIs	**Total Health Costs of RTIs**	**Total Health Costs of RTIs**	**Total Health Costs of RTIs**



Source: Authors' calculations

Putting these numbers into perspective, in Kazakhstan, the overall health care costs resulting from RTIs were similar to the 2017 cumulative expenditures for rehabilitative and palliative care within the state-guaranteed basic package.[10] In Kyrgyzstan, the RTI costs exceeded the expenditures for emergency medical services within the mandatory health insurance fund;[11] and in Tajikistan, they exceeded the expenditures for ambulatory care within the national budget.[12]

In Kazakhstan, nearly half of health care costs (46 percent, Int$22.8 million) were due to injuries suffered by women in road crashes. Uzbekistan presented very different figures – only Int$0.66 million (equivalent to 2 percent of health care costs). In this study, this distribution of costs is mainly driven by incidence, not by consumed care, given the data that was available.[13] However, it should be borne in mind that fatality

10 Social Health Insurance Fund Annual Report, 2017 https://fms.kz/o-fonde/otchetnost/]

11 Law No. 216 (21) of 27.12.2017 on the budget of the Mandatory Health Insurance Fund, http://cbd.minjust.gov.kg/act/view/ru-ru/111725?cl=ru-ru

12 Law on the state budget of the Republic of Tajikistan for 2016, http://minfin.tj/downloads/zakon01032016.pdf

13 Road traffic crash data disaggregated by gender are not recorded and/or reported for Tajikistan and Kyrgyzstan.

and injury numbers alone do not tell the whole story of the burden of road crashes within the health care system: the individual determinants of crash casualties that are predictive for health care consumption are also important. For example, the effects of age and gender on costs has been confirmed (van Beeck, 1996; Achit et al., 2014; Carnis et al., 2014; Shen et al., 2015; Achit, 2015; Papadakaki et al. 2016; and Devos et al., 2017). Older people suffered higher costs related to crash casualties than younger ones, and females had higher average costs. The higher costs for older casualties may be due to the fact that aging reduces the injury-related biomechanical load limits and is accompanied by increasing comorbidities and longer recovery periods. For females, the higher costs are determined by differences in injury patterns compared to men; for example, women were more often involved in a road crash as vulnerable road users. Therefore, road safety policymakers should take the broad variability of health care costs into account.

Health Care Costs Related to RTC Casualties and Their Impact on Households

The weighted mean cost per road traffic crash (RTC) casualty was estimated to be Int$1,166 in Kazakhstan (equivalent to 129 percent of current health expenditures (CHE) per capita, or 4.7 percent of GDP per capita); Int$453 in Kyrgyzstan (198 percent of CHE per capita, or 9.7 percent of GDP per capita); Int$1,211 in Uzbekistan (312 percent of CHE per capita, or 18.8 percent of GDP per capita); and Int$674 in Tajikistan (320 percent of CHE per capita, or 21.8 percent of GDP per capita).

For all injury and health care types, the cost per event generated by pedestrians was the highest in all four Central Asian countries (Table 1.1). However, this group was not the largest one in the structure of road crash casualties (see Appendix B, Tables B19 – B20). Motorized four-wheel users (drivers and occupants) registered the second-highest cost per event in Kyrgyzstan, similar to Kazakhstan. However, in Kazakhstan, a significant share of the health care cost per event (Int$1099) was due to the use of air ambulances, which were used predominantly to attend to crashes involving motorized four-wheelers.

Table 1.1 Health Care Cost Per Event by Road User, 2016 (in Int$)

	PEDESTRIANS	CYCLISTS	MOTORIZED 2 OR 3-WHEELER USERS	MOTORIZED 4-WHEELER USERS
Kazakhstan				
Cost per event	1,179	898	720	1,099
% of CHE per capita	136.3	103.8	83.3	127.2
% of GDP per capita	4.9	3.8	3.0	4.6
Kyrgyzstan				
Cost per event	492	395	402	424
% of CHE per capita	214.8	172.4	175.7	185.2
% of GDP per capita	10.5	8.4	8.6	9.1
Tajikistan				
Cost per event	753	686	545	617
% of CHE per capita	357.7	326.0	258.8	293.0
% of GDP per capita	24.3	22.2	17.6	19.9
Uzbekistan				
Cost per event	1,479	1,018	1,121	1,066
% of CHE per capita	380.6	262.1	288.4	274.3
% of GDP per capita	22.9	15.8	17.4	16.5

Source: Authors' calculations

At the same time, in Kazakhstan and Tajikistan motorized four-wheel users accounted for the highest aggregate health care costs, as well as the highest costs for each type of care (Table 1.2). These differences are mainly driven by incidence, not by consumed care and its subsequent costs. For instance, cyclists incurred higher average hospital costs for all AIS 3+ (severe) injuries, compared to motorized four-wheel users (Int$2,087 vs. Int$2,054 in Uzbekistan; Int$349 vs. Int$346 in Kyrgyzstan; Int$1,029 vs. Int$1,030 in Tajikistan; and Int$953 vs. Int$946 in Kazakhstan).

Table 1.2 Costs by Road User and Type of Care Consumed, 2016. (In Int$)

	PEDESTRIANS	CYCLISTS	MOTORIZED 2 OR 3-WHEELER USERS	MOTORIZED 4-WHEELER USERS
Kazakhstan				
Prehospital care (EMS)	308,531	32,822	10,369	4,343,212
ED care	35,614	3,882	948	56,709
Outpatient care	1,916,826	210,136	51,708	3,043,422
Hospital care	6,901,749	669,390	166,833	10,141,593
Long-term care	9,839,719	623,203	160,170	10,850,393
Total	***19,002,439***	***1,539,433***	***390,028***	***28,435,329***
Kyrgyzstan				
Prehospital care (EMS)	79,632	9,864	8,076	71,003
ED care	-	-	-	-
Outpatient care	260,819	33,073	26,842	233,935
Hospital care	2,218,525	260,064	213,823	1,892,388
Long-term care	1,833,848	133,702	115,586	1,180,329
Total	***4,392,824***	***436,703***	***364,327***	***3,377,655***
Tajikistan				
Prehospital care (EMS)	5,565	1,035	97	7,591
ED care	-	-	-	-
Outpatient care	40,593	10,421	737	53,812
Hospital care	664,710	132,354	9,625	795,535
Long-term care	526,450	65,942	5,089	525,717
Total	***1,237,318***	***209,752***	***15,548***	***1,382,655***
Uzbekistan				
Prehospital care (EMS)	212,962	72,599	62,825	258,538
ED care	-	-	-	-
Outpatient care	1,631,154	590,313	519,655	1,935,060
Hospital care	6,773,322	1,764,547	1,653,588	6,287,983
Long-term care	6,164,853	1,043,163	1,068,436	4,451,096
Total	***14,782,291***	***3,470,622***	***3,304,504***	***12,932,677***

Source: Authors' calculations

In Kyrgyzstan, a mean out of pocket (OOP) spending of Int$259 by traffic-injury affected households in the lowest income quintile imposes a financial burden of 5 percent of mean annual income. Despite this being an average figure, it is of concern because many households might also face a catastrophic or "regressive" financial burden, considering the large range between the minimum and maximum annual income in this quintile (Int$206 and Int$7,189). For instance, the spending on traffic injury treatment by households with a very low income could be as much as 125 percent of their annual income. However, excessive OOP payments may also hinder access to health care, and poorer households might be less likely to experience catastrophic payments, since they might avoid or delay necessary health care (Brown, Hole, and Kilic 2014). Further, a financial burden of 3 percent and 1 percent is produced for households from the second- and fifth-highest income quintiles, respectively.

Kazakhstan presents similarities in terms of average figures for financial burden: a financial burden of 6 percent and 1 percent of mean annual income is imposed to households in the lowest and highest income deciles.

In Tajikistan, health care for a traffic injury (Int$445) produces a catastrophic financial burden on households from the lowest income decile (23 percent), and a low financial burden (2 percent) of mean annual income on households from the highest income decile. Hence, some of the poorest 10 percent of households have borne a "regressive" financial burden; that is, a financial burden exceeding 100 percent of the mean annual income. These figures raise a series of issues in terms of both economic burden and equity in access to health care for the poorest households.[14] OOP spending is acting both to deter people from seeking necessary care and, once advice has been sought, from receiving the most appropriate treatment.

Health Care Costs of Road Traffic Injuries

The patterns of the injuries with highest aggregate costs are quite similar in these countries (Table 1.3). Road crash casualties with a head injury consumed by far the highest share of total costs (from 30 to 40 percent), caused by the highest incidence rate and highest mean cost per casualty. Further, injuries to lower and upper extremities were in the top three injuries with the highest aggregate costs. Polytrauma, which had the highest cost per casualty, was associated with the lowest aggregate costs.

Table 1.3 Health Care Costs by Injury Type (Body Region), 2016 (In Int$)

	KAZAKHSTAN	KYRGYZSTAN	TAJIKISTAN	UZBEKISTAN
Injuries to Head	15,303,240	2,536,400	1,175,315	10,212,874
Injuries to Neck	4,603,092	633,961	193,628	2,309,845
Injuries to Thorax	4,760,494	749,190	262,372	3,406,245
Injuries to Abdomen	3,912,294	660,749	227,094	2,565,701
Injuries to Upp Ext	6,889,042	1,192,810	268,373	4,565,444
Injuries to Low Ext	11,714,468	2,190,556	461,704	8,577,373
Injuries to Multiple Regions (Polytrauma)	2,013,184	563,700	246,429	2,645,620
Injuries to Unspecified Region	171,415	44,142	10,359	206,991

Source: Authors' calculations

14 An earlier study on Tajik households that was not specifically related to RTIs found that there are significant differences in health care use rates across socioeconomic groups, with the differences between groups being related to the ability to pay (Falkingham 2004).

The average health care cost related to a fatality was estimated to be Int$282 for Kazakhstan, Int$124 for Kyrgyzstan, Int$137 for Tajikistan, and Int$404 for Uzbekistan. The average share of fatalities in the total health care cost was less than 2 percent in Kazakhstan and Kyrgyzstan. A higher share was estimated in Uzbekistan and Tajikistan (4.2 percent, and 7.6 percent, respectively). (Table 1.4) These fairly low values suggest that a large number of deaths (approximately 70 percent) occurred at the crash scene, before any intervention of the health care system could take place. This pattern is also confirmed in other reports, which have found that the vast majority of road traffic deaths in LMICs occurs in the prehospital phase (WHO 2018). Therefore, increasing access to prehospital care, and improving national trauma care system capabilities and capacities is crucial.

Table 1.4 Health Costs of Road Crash Fatalities, 2016 (In Int$)

	KAZAKHSTAN	KYRGYZSTAN	TAJIKISTAN	UZBEKISTAN
Death at crash scene	63,694	24,918	7,362	182,123
Dead on arrival at the hospital	993	-	1,513	-
Death at ED	596	-	-	-
Death at hospital	825,516	91,314	207,115	1,278,696
Total	***890,799***	***116,232***	***215,990***	***1,460,819***
Percentage of Total Health Care Costs	1.8	1.4	7.6	4.2

Source: Authors' calculations

The health care costs attributable to RTIs reflect additional expenditures that countries incur because of road crashes. This includes the computed costs of services and products (medical procedures, investigations, consultations, etc.) that are needed to restore the health status of the person injured, ideally to the level prior to the road crash. Table 1.5 summarizes such expenditures and their distribution. As expected, the health care cost distribution is skewed, with road crash casualties that are admitted for inpatient acute care, and early or late consequences of injury accounting for more than 80 percent of the total costs in all four countries. This is strongly correlated with injury patterns, and with the risk of permanent medical impairment.

Cost variations from country to country are mainly due to different approaches to health care delivery and financing, including the way trauma care is organized. For instance, in Kazakhstan, prehospital emergency care was provided by both ground and air ambulances. The latter accounted for about Int$3.85 million, with an average cost per journey of Int$7,400. Also, the designed pathway for crash casualties included rehabilitative care during the period of hospitalization immediately following the injury (the first stage of rehabilitation). This accounted for more than Int$16 million, with an average cost per discharge of Int$3,738.

Prehospital emergency care accounted for less than 2 percent of aggregate health care costs of RTIs in Kyrgyzstan, Tajikistan, and Uzbekistan. This is mainly due to the extremely low use of resources within the crash casualty pathway, ranging from 1 percent in Tajikistan to 21 percent in Uzbekistan, of estimated injured casualties who were attended by an ambulance. More crash casualties were transported by passers-by, which tends to complicate injuries as a result of poor handling.

Table 1.5 Costs by Type of Care Consumed, 2016 (In Int$)

	KAZAKHSTAN		KYRGYZSTAN		TAJIKISTAN		UZBEKISTAN	
	ABS.	%	ABS.	%	ABS.	%	ABS.	%
Prehospital care	4,694,934	9.5	168,574	2.0	14,287	0.5	606,923	1.8
ED care	97,153	0.2	-	-	-	-	-	-
Outpatient care	5,222,092	10.6	554,669	6.5	105.563	3.7	4,676,182	13.6
Hospital care	17,879,564	36.2	4,584,800	53.5	1,602,225	56.3	16,479,441	47.8
Long-term care	21,473,485	43.5	3,263,465	38.1	1,123,198	39.5	12,727,547	36.9
Total	***49,367,228***		***8,571,508***		***2,845,273***		***34,490,093***	

Source: Authors' calculations

This distribution of RTI-related costs, with a major part of the burden related to hospital and long-term care and reduced use of prehospital emergency care, suggests the need to reevaluate the crash casualty pathway ("chain of care") in order to avoid preventable deaths and permanent medical impairment or disability, and to limit the severity of injuries. A series of time-sensitive actions are essential in order to provide effective care for the injured, and a chain of opportunities for intervening across a longer timescale –from care at the crash scene, transport, and facility-based emergency care to rehabilitation. This study highlights both the appropriateness of care and potential areas for cost containment, for example by reducing the risk of costly episodes of inpatient and rehabilitative care. For instance, it was demonstrated that the risk of sustaining a permanent medical impairment due to a thoracic injury of AIS 4+ (excluding spine) is rather low compared with injuries of the same AIS level in other body regions (Malm 2008). Thus, a person surviving an AIS 4+ thoracic injury (excluding spine) usually recovers without functional reduction. This is also applicable to those who survive abdominal AIS 4+ injuries. On the other hand, there are injuries that cause immediate and permanent disability (AIS 4+ injuries to cervical, thoracic, and lumbar spine), and thus generate health care consumption over a long period of time for inpatient services, medical appliances, and so on. In this case, preventive interventions are required from outside the health care system.

This study does not elucidate the costs of post-impact care versus the benefits of preventing injury in RTCs. However, international research has shown that improved organization and planning for emergency care can be carried out at a reasonable cost and can lead to more appropriate use of resources, improved care, and better outcomes (White, Williams, and Greenberg 1996). In LMICs most of the effective prehospital strategies are basic and inexpensive, and the lack or scarcity of high-tech interventions need not deter efforts to provide adequate care. Significant reductions in preventable deaths can also be achieved through improvements in the trauma care system. Previous studies have indicated an average reduction of 50 percent in medically preventable deaths; and population-based and trauma registry studies have shown around a 20 percent reduction in mortality (Simons et al. 1999; Mann et al. 1999; Brennan et al. 2002). And the intervention costs per life (or life-year) saved are very low compared to other medical interventions (Durham et al. 2006; Rotondo et al. 2006).

In this study, serious injuries (AIS 3+) and polytrauma accounted for only a small share of acute inpatient cases, but constituted the largest share of aggregate hospital costs in three of these four countries . Thus, in Tajikistan 21 percent, and in Uzbekistan 18 percent of hospitalized cases generated almost 57 percent of the costs for this type of care; in Kazakhstan, 19 percent of hospitalized cases accounted for 47 percent of those costs. In Kyrgyzstan, 21 percent of crash casualties who were hospitalized for serious injuries (AIS 3+) or polytrauma contributed to 36 percent of the costs. At the same time, the weighted mean cost per hospital stay of all road user groups was estimated to be Int$817 for Kazakhstan, Int$325 for Kyrgyzstan, Int$702 for Tajikistan, and Int$1,215 for Uzbekistan.

More detailed analyses of care category costs, and costs related to injury severity have provided further insight into the factors that influence these costs, and useful information for both clinical quality improvement activities and targeted planning and prevention initiatives. Serious injury and polytrauma should not be regarded, either ethically or economically, as being "equal" to a large number of slight injuries that may result in the same costs; similarly, preventing serious injuries should not be preferred to preventing a larger number of slight injuries. The risks of permanent medical impairment for slight injuries (AIS 1-2) are much lower than the risks for serious injuries (AIS 3+), but because slight injuries (AIS 1-2) are so frequent, a significant number of impairments have been sustained from such injuries. For instance, slight injuries (AIS 1-2) contributed to nearly 40 percent of the cases of permanent medical impairments in four Central Asian countries.[15] This corresponded to Int$4.60 million in Uzbekistan, Int$0.37 million in Tajikistan, Int$1.02 million in Kyrgyzstan, and Int$7.24 million in Kazakhstan, as costs for inpatient subacute and rehabilitative care. At the same time, the weighted mean cost per treated case was estimated to be Int$2,986 for Kazakhstan, Int$687 for Kyrgyzstan, Int$1474 for Tajikistan, and Int$2,902 for Uzbekistan.

Special attention should be given to the significant share accumulated by long-term care services in aggregate health care costs. A deeper analysis is needed to understand the main cost drivers; however, a dual situation is highlighted. On the one hand, long-term care consumption is required (and is often available) to manage injuries, thereby enhancing the impact of emergency and acute inpatient care, as well as limiting their physical and psychological impact. However, rehabilitative care was identified only in Kazakhstan, while in the case of Kyrgyzstan, Tajikistan, and Uzbekistan, inpatient subacute care for early or late consequences of injury is provided. On the other hand, long-term care raises issues regarding the organization of the national trauma system and the efficacy of acute care delivered at previous stages, thus preventing, as far as possible, the development of permanent disability.

Avoidable Costs

RTIs have not always been considered a preventable health problem, although it has long been known that they are related to modifiable determinants (Plasencia and Cirera 2003). Tackling RTIs is not substantially different than tackling other major health problems. Interventions to prevent RTIs and reduce related mortality, morbidity, and disability include modifying the various factors involved in collisions. These factors play a role before, during, and after a crash, and are located both inside and outside the scope of the health care system.

This study also considered the potential evolution of costs, if established road safety targets were achieved. The costs from the health care system perspective are important in informing the future prioritization of health care resources, especially in regard to considering the financing arrangements in place (payment mechanisms, etc.). To show the effects of interventions, the estimated health care costs for 2016 (the "status quo" scenario) was compared with three hypothetical scenarios – a "moderate," a "median," and an "optimistic" one – in which the countries would reduce their average road

15 Based on PMI 5%+ scale.

crash mortality and injury rates by 25, 50, or 75 percent, by 2025. The redistribution of injury outcomes as a result of changes in the various crash determinants—for example, improvements in protective vehicle technology and road infrastructure, and changes in collision configurations--is a difficult task. Therefore, the prediction of how the health care costs related to road crashes would change in the short run as a result of reducing crash deaths and injuries (including reducing their severity) is based on the assumption of keeping all other variables constant.

The cost model showed that the reduction in deaths and injuries from road crashes would have a notable positive effect on expenditures for health care. The cumulative costs to be avoided by the health system by 2025, in the case of the “median” scenario, would amount to Int$28.1 million for Kazakhstan, Int$5.2 million for Kyrgyzstan, Int$1.9 million for Tajikistan, and Int$22.5 million for Uzbekistan (See Table 1.6). Consequently, the health care expenditure for RTIs would decline to 0.15 percent of CHE in Kazakhstan, 0.18 percent in Kyrgyzstan, 0.05 percent in Tajikistan, and 0.12 percent in Uzbekistan. However, this study does not take into account the likely linear or nonlinear relationship between reducing mortality and injury rates, and decreasing RTI-related health care costs – an issue that should be explored through further research.

The RTI health care cost burden on these four health care systems persisted at still significant levels in all three scenarios. For instance, the share of the weighted mean cost per casualty in the CHE per capita, in the case of the “median” scenario, was estimated to be 111 percent in Kazakhstan, 152 percent in Kyrgyzstan, 207 percent in Tajikistan, and 217 percent in Uzbekistan. This was mainly determined by the injury patterns, and the risk of permanent medical impairment. Thus, changes in injury patterns should also be considered an integral part of an overall reduction of injury rates. Reducing the severity of injuries would of course translate into decreasing health care costs.

Since injury is an immediate consequence of the impact of the crash, preventive interventions aim to reduce or eliminate this impact in the first place through imposing speed limits and improving enforcement and road design are important. There is considerable international evidence on the relationships between impact velocity, impact speeds, and the probability of fatal and serious injury across a range of common crash scenarios (Jurewich 2016). Much of this research points to the fact that even a small reduction in speed can lead to considerable reductions in road injuries. For example, nearly all pedestrians survived a collision with the front of a car at a collision speed of 20 km/hr, while at 80 km/hr, less than half survived (Rosen, Stigson, and Sander 2011). For impact speeds of up to 40 km/hr, 35 percent of cyclists suffered head injuries, whereas this rose to 72 percent of the cyclists at speeds above 40 km/hr (Otte et al. 2015). Furthermore, motorcycle helmet use reduced AIS 1 head injuries by 34 percent, AIS 2 head injuries by 22 percent, and AIS 3+ head injuries by 21 percent (Otte et al. 2013). And newer vehicles (models from 2009 and later) generally carried less risk of injury in frontal collisions with belted occupants compared to older vehicles, reducing the odds of AIS 2+ injury by 31 percent and of AIS 3+ by 55 percent (Forman et al. 2019).

Table 1.6 RTI-Related Health Care Costs Avoided in Various Scenarios (In Int$)

	COST AVOIDED	% OF CHE	COST PER RTC CASUALTY	% OF CHE PER CAPITA
Kazakhstan				
Moderate scenario	14,919,993	0.24	1,038	120
Median scenario	28,133,096	0.15	960	111
Optimistic scenario	39,634,065	0.07	880	102
Kyrgyzstan				
Moderate scenario	2,840,584	0.31	402	176
Median scenario	5,228,334	0.18	348	152
Optimistic scenario	7,093,238	0.08	298	130
Tajikistan				
Moderate scenario	1,083,711	0.09	555	264
Median scenario	1,920,267	0.05	435	207
Optimistic scenario	2,503,474	0.02	314	149
Uzbekistan				
Moderate scenario	12,680,540	0.21	1,021	263
Median scenario	22,502,475	0.12	841	217
Optimistic scenario	29,777,109	0.05	662	170

Source: Authors' calculations

If there were a reduction in road crash fatalities only, it was estimated that there would actually be an increase expenditures in all health care cost categories due to increased consumption of care. For instance, if the number of road fatalities in these countries were cut in half due to effective safety and infrastructure programs, and/or effective interventions from the health care system, there would be cumulative higher aggregate costs of Int$5.2 million, ranging from Int$0.14 million in Kyrgyzstan to Int$2.38 million in Kazakhstan. This would correspond to an increase in the share of CHE by 2 percent in Kyrgyzstan, 6 percent in Kazakhstan and Uzbekistan, and 27 percent in Tajikistan. Road safety and health care policymakers should take this into account, and should bear in mind that effectively treating the people whose deaths were prevented would require adequate organization of the national trauma care system and appropriate allocation of financial resources to fund it.

CHAPTER 2:

THE EFFECT OF RTI MORTALITY AND DISABILITY ADJUSTED LIFE-YEARS (DALYS) ON ECONOMIC GROWTH

As mentioned in the introduction to this report, road traffic injuries (RTIs) are a major cause of death and disability worldwide, especially in lower- and middle-income countries (LMICs); and for the relatively young population that they represent, they are a leading cause of death and disability. Progress has been made on improving road safety in recent decades, although many countries will not meet the United Nations Sustainable Development Goal (SDG) 3.6, which had set a target of reducing RTI mortality and injuries by 50 percent by 2020, compared to its level in 2010.[16]

In this chapter we will evaluate the impact of RTI from a macroeconomic perspective in Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan. This analysis will complement and extend the results of the cost of injury (COI) estimates presented in the previous chapter.

In several studies, Wijnen and his coauthors have pointed out that there are five types of socioeconomic cost categories that are related to RTI (Wijnen 2020; Wijnen et al. 2019; Wijnen and Spidonk 2016):

1. **Medical Costs**: The costs of medical treatment and rehabilitation from injuries resulting from road crashes;
2. **Production Loss**: Loss of production and consumption due to the loss of human capacities;
3. **Human Costs**: Loss of quality of life and life-years;
4. **Property Damage**: Damage to vehicles, roads, roadside objects, and freight;
5. **Administrative Costs**: Costs of police and other emergency services, insurance, and legal costs.

They have concluded that the largest share of the RTI burden is that of the human costs. In a recent evaluation of RTI burden carried out in Kazakhstan, Wijnen (2021) concluded that the total costs of road crashes were estimated at $6.8 billion in 2012, which corresponds to 3.3 percent of the GDP. Using a value of statistical life (VSL) approach, the aggregate human costs were estimated at $5.5 billion, accounting for 81.1 percent of the total costs. Property damage (mainly damage to cars) accounted for a share of 11.3 percent of the total costs, while production loss accounted for 5.9 percent.

16 Definitive data for 2020 are not available yet.

Administrative and medical costs were relatively small cost components, amounting to 1.3 and 0.4 percent of the total costs, respectively.

This chapter's purpose is twofold. First, we provide an evaluation of human costs for the four countries of interest. For Kazakhstan only, Wijnen (2021) derived the VSL from a contingent valuation questionnaire administered to more than 1,000 individuals; his data refers to 2012. The analysis presented in this chapter uses more recent data, and estimates the VLS for all four countries of interest, by exploiting the empirical link between average income and VSL derived by Viscusi and Masterman (2017). Compared to other studies, including Viscusi and Masterman's, which measure VSL in current US dollars, the estimates of VSL adjusted for purchasing power parity (PPP) are also reported, to facilitate a meaningful comparison with the US estimate, which is the usual reference in this literature, and also among the four countries. For Kazakhstan, by far the richest of the four countries, the PPP-adjusted VLS estimate is significantly larger ($3.6m) than the one by Wijnen (2021) (about $0.73 million).

Second, we add to the list of socioeconomic cost categories a conceptually dynamic component, which has been rather overlooked so far in the literature; that is, the effect of RTI on future economic growth. All of the cost components in Wijnen's taxonomy are static and do not account either for the long-run effects of RTI on economic systems, or for the adjustments that economies undertake in reaction to RTI. For instance, in the traditional analysis, production loss is taken as the potential production of one individual. It assumes that individuals will work full-time and continuously for the rest of their working years, regardless of whether they were employed, unemployed, or inactive on the date of the road accident. But in reality, the economic system adapts to a loss of labor supply in several ways, which may well compensate for the loss. In most cases, there is a reserve of idle labor supply (the unemployed) that can be tapped into. However, such compensation is hardly complete, because specific human capital takes time and resources to be replaced. There are also other potentially relevant mechanisms at work that need to be considered: for example, as with mortality and morbidity due to other causes, RTI affects life expectancy, which in turn affects saving and investment decisions, and thus influences consumption and prices through a multitude of economic adjustments (Bloom et al. 2019).

The analysis presented here shows that RTI has a negative effect on long-run economic growth that is sizeable and should not be neglected. We estimate that reducing RTI-attributable disability adjusted life-years (DALYs)--a combined measure of mortality and morbidity--in the working-age population by 10 percent would add 0.55 percentage points to the total amount of achievable economic growth in a period of more than 30 years. This would also yield an additional income flow with a net present value (NPV) equivalent to about 5 percent of 2019 GDP in Kazakhstan, Kyrgyzstan, and Uzbekistan, and 2.7 percent in Tajikistan. These figures are far from negligible, because they are similar to our assessment of the human costs: 6.4 percent in Kazakhstan; 4.7 percent in Kyrgyzstan; 2.7 percent in Tajikistan; and 3.1 percent in Uzbekistan.

These results suggest that the dynamic effects of RTI on economic development are important and should not be neglected. In fact, the human costs and the dynamic macroeconomic costs are by far the main cost components to be considered.

This chapter develops as follows. After describing RTI DALYs and mortality in the four countries, the focus turns first to the evaluation of the human costs and subsequently to the estimation of the effect of RTI on economic growth.

DATA

The analysis exploits data from the Global Burden of Disease Study (GBD), a long-running study that is based on what may be the largest repository of health data, the Global Health Data Exchange (GHDx). Since 1990 the GBD has estimated the number of deaths, DALYs, Health-Adjusted Life Expectancy (HALE), and other metrics specific to a large number of diseases and injuries, by age group, for all countries. The estimates are continually revised, as new information reaches the GHDx.

DALYs combine premature mortality and morbidity by weighting life-years lived with disability: the weights are proportional to the severity of the disability. For instance, a person expected to live 75 years who has a road accident at age 50 that would imply a disablement of 50 percent, followed by a premature death at age 70, will lose 15 DALYs: 5 DALYS for premature death, and 10 for the time spent with disability. The corresponding health-adjusted life-years--that is life-years spent in good health--are 60.

HALE is a closely related concept that adjusts life expectancy by weighting the years lived in disability to produce life expectancy in good health. For instance, a life expectancy of 75 years combined with 10 years lived with disability (on average), with a disability weight of 0.5, corresponds to a HALE of 70 years.

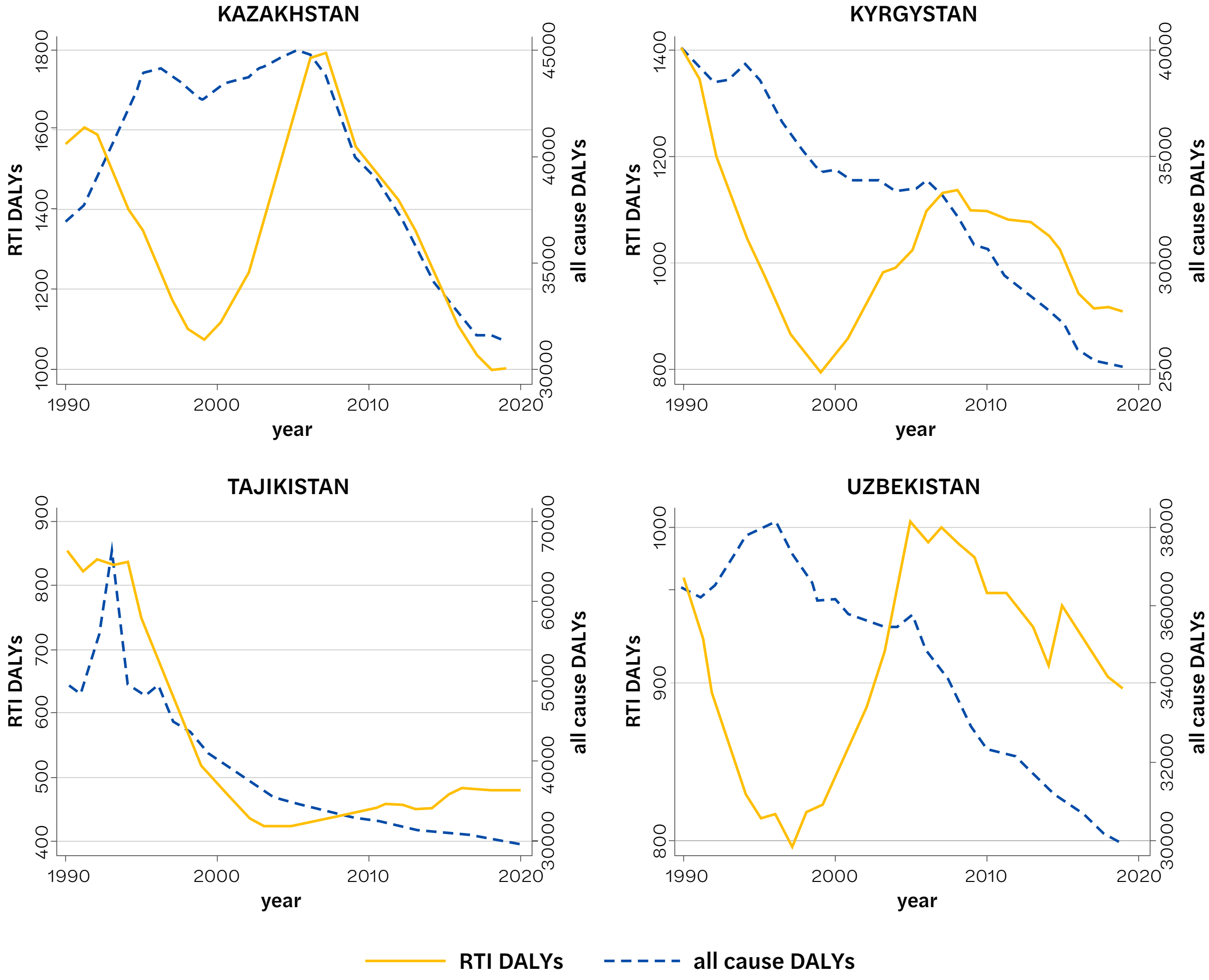
This section documents the evolution of RTI and all-cause DALYs and deaths in the four countries of interest between 1990 and 2019—the last year for which data are available—distinguishing between the whole population and the working-age population (ages 15-64). We also relate the health burden of RTI with GDP per capita

Figure 2.1 shows a similar pattern for RTI DALYs in Kazakhstan, Kyrgyzstan, and Uzbekistan. After a sharp decline between 1990 and the late 1990s, the number of DALYs due to RTI increased until about 2010 and then started declining. In Tajikistan we also observe the decline during the 1990s, but thereafter the pattern is that of a mild but steady increase. Abdunazarov et al. (2020) have suggested that the initial decline might be to some extent a statistical artifact due to the switch from Soviet statistical administration to national statistics, although this can hardly be the full story. The subsequent increase could be explained both by improved statistics recording, and by strong economic performance in the first decade of the new century, which caused a large increase in motorization. The more recent decline is likely associated with policy interventions and improved road safety. In 2019 RTI DALYs were 954 per 100,000 inhabitants in Kazakhstan. Kyrgyzstan and Uzbekistan followed with 915 and 896 respectively, while Tajikistan was much lower at 486.

The dashed line represents all-cause DALYs, a comprehensive measure of population health. We observe a decline in all-cause DALYs (that is, an improvement of population health) starting around 2010 in all of the countries except Tajikistan, where the decline had started earlier, soon after independence in the early 1990s. In 2019, all-cause DALYs were the highest in Kazakhstan (31,424 DALYs per 100,000 inhabitants), lowest in Kyrgyzstan (25,263), and equal to 28,281 in Tajikistan and 29,876 in Uzbekistan.

Similar patterns hold for RTI deaths (Figure 2.2). In 2019 they were around to 15 per 100,000 inhabitants in Kazakhstan, Kyrgyzstan, and Uzbekistan, and much lower in Tajikistan.

Figure 2.1. RTI and All-Cause DALYs per 100,000 population

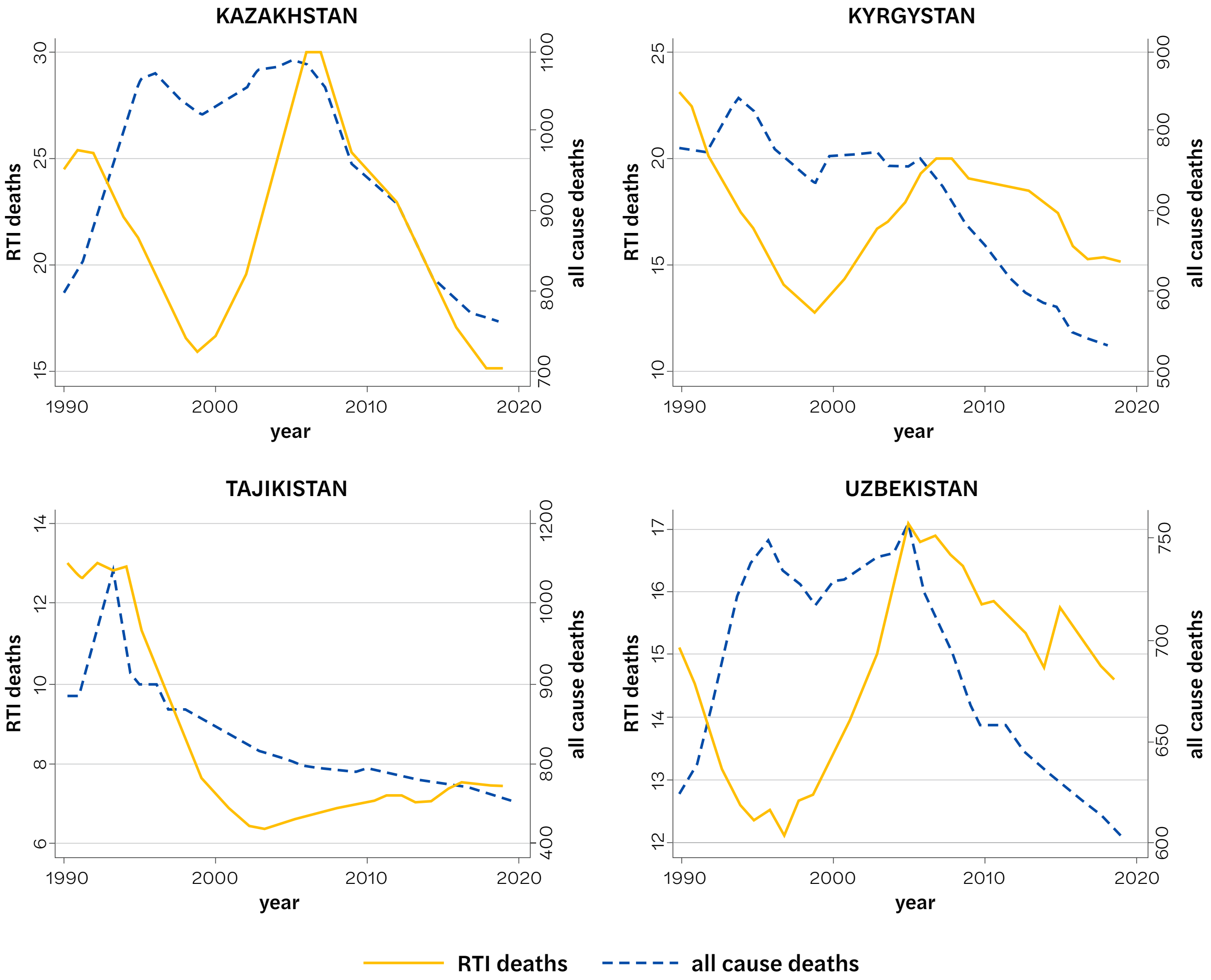


Source: GBD 2019

Figures 2.3 and 2.4 report DALYs and deaths due to RTI for the working-age population (15-64 years), and for the whole population. RTI DALYs and mortality are always higher in the working-age population compared to the whole population.[17] In 2019, RTI DALYs and deaths in the working-age population were between 27 percent (in Uzbekistan) and 36 percent (in Kyrgyzstan), higher than the level registered for the whole population: this gap is persistent throughout the study period. RTI DALYs in the working-age population are between 1100 and 1250 per 100,000 inhabitants in Kazakhstan, Kyrgyzstan, and Uzbekistan, and just half as much in Tajikistan. RTI deaths range between 18.6 and 20.6 in in Kazakhstan, Kyrgyzstan, and Uzbekistan, and are just below 10 in Tajikistan.

17 This fact reflects the higher mobility of the younger population, partly related to commuting from the workplace and partly to less sedentary lifestyles.

Figure 2.2 RTI and All-Cause Mortality per 100,000 Population



Source: GBD 2019

Figure 2.3 RTI DALYs by Age Group

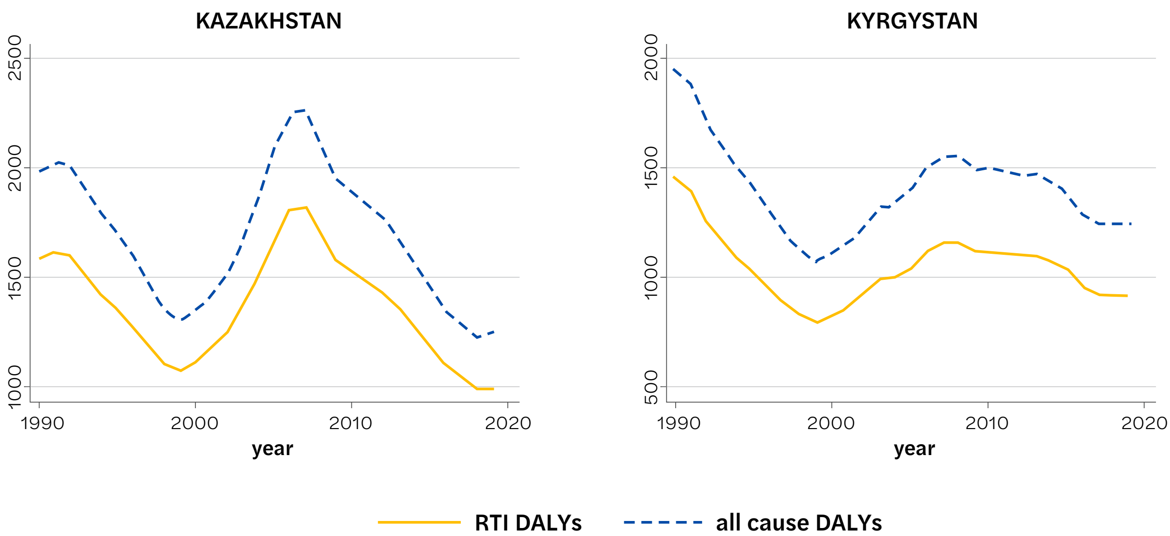
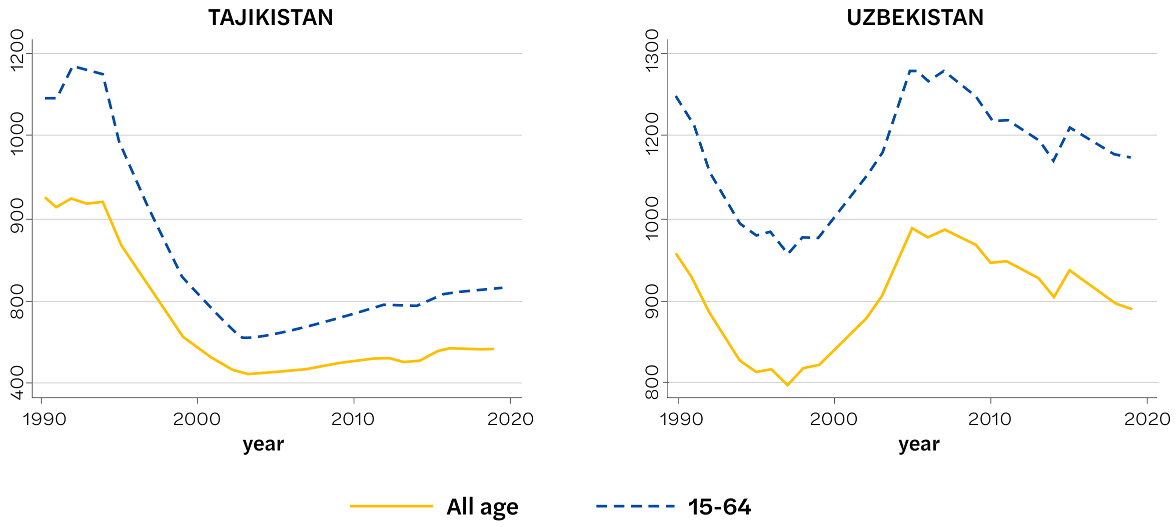
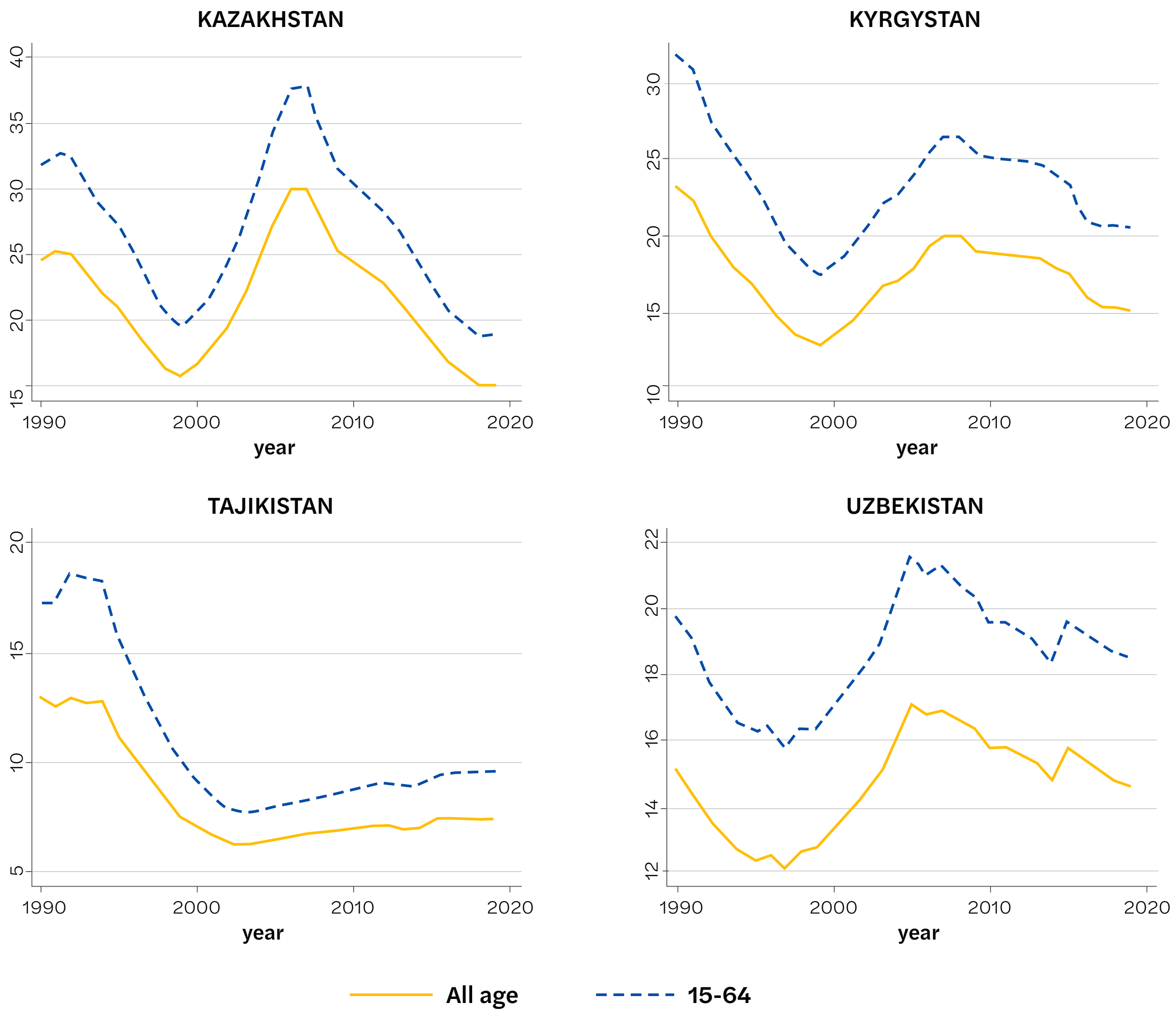


Figure 2.3 (CONT) RTI DALYs by Age Group



Source: GBD 2019

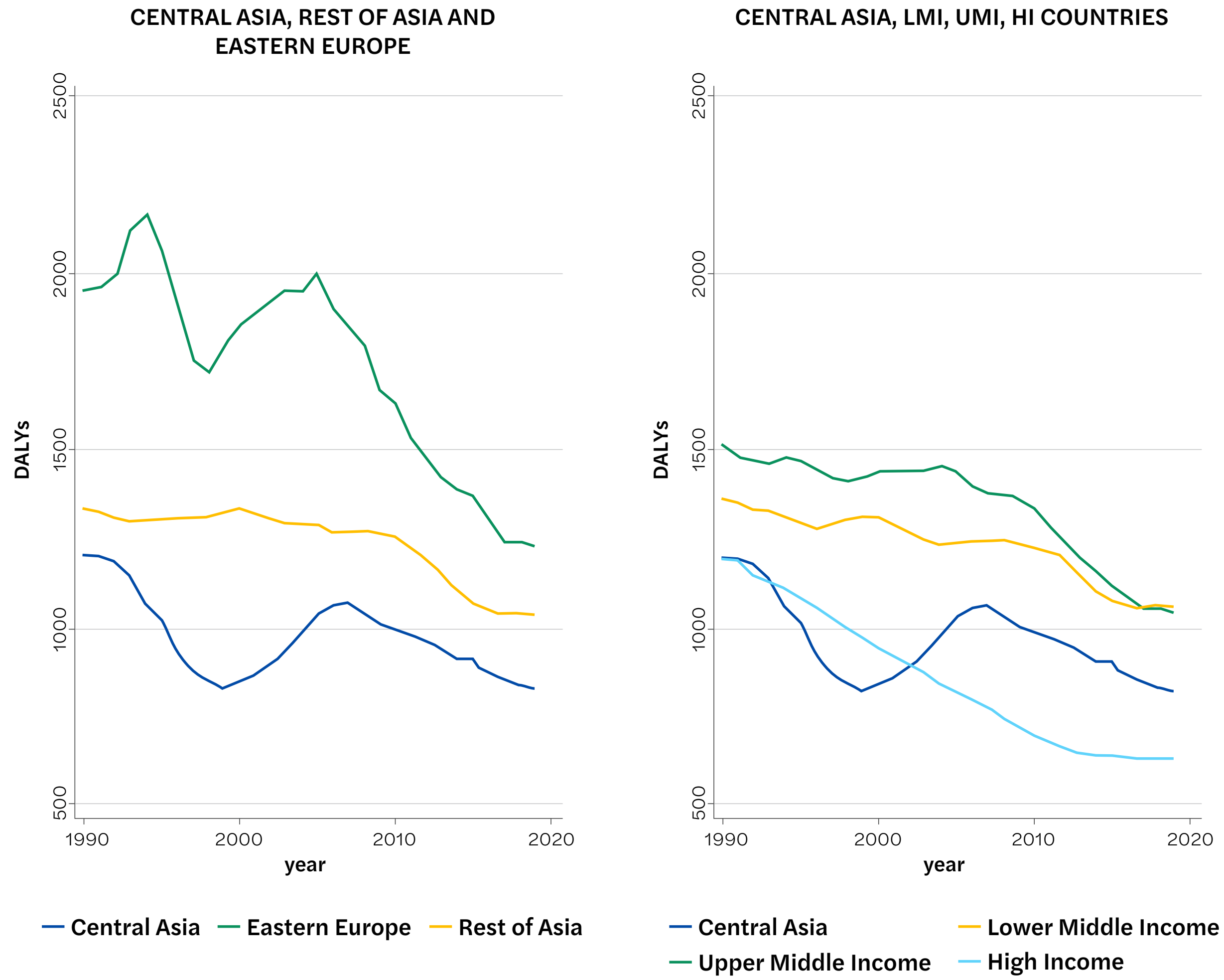
Figure 2.4 RTI Mortality by Age Group



Source: GBD 2019

In the leftmost panel of Figures 2.5 and 2.6, for the sake of comparison we report the RTI DALYs and RTI deaths in the Central Asian countries; for Asia overall; and for Eastern Europe.

Figure 2.5 RTI DALYs per 100,000 Population, by Region and Income Classification

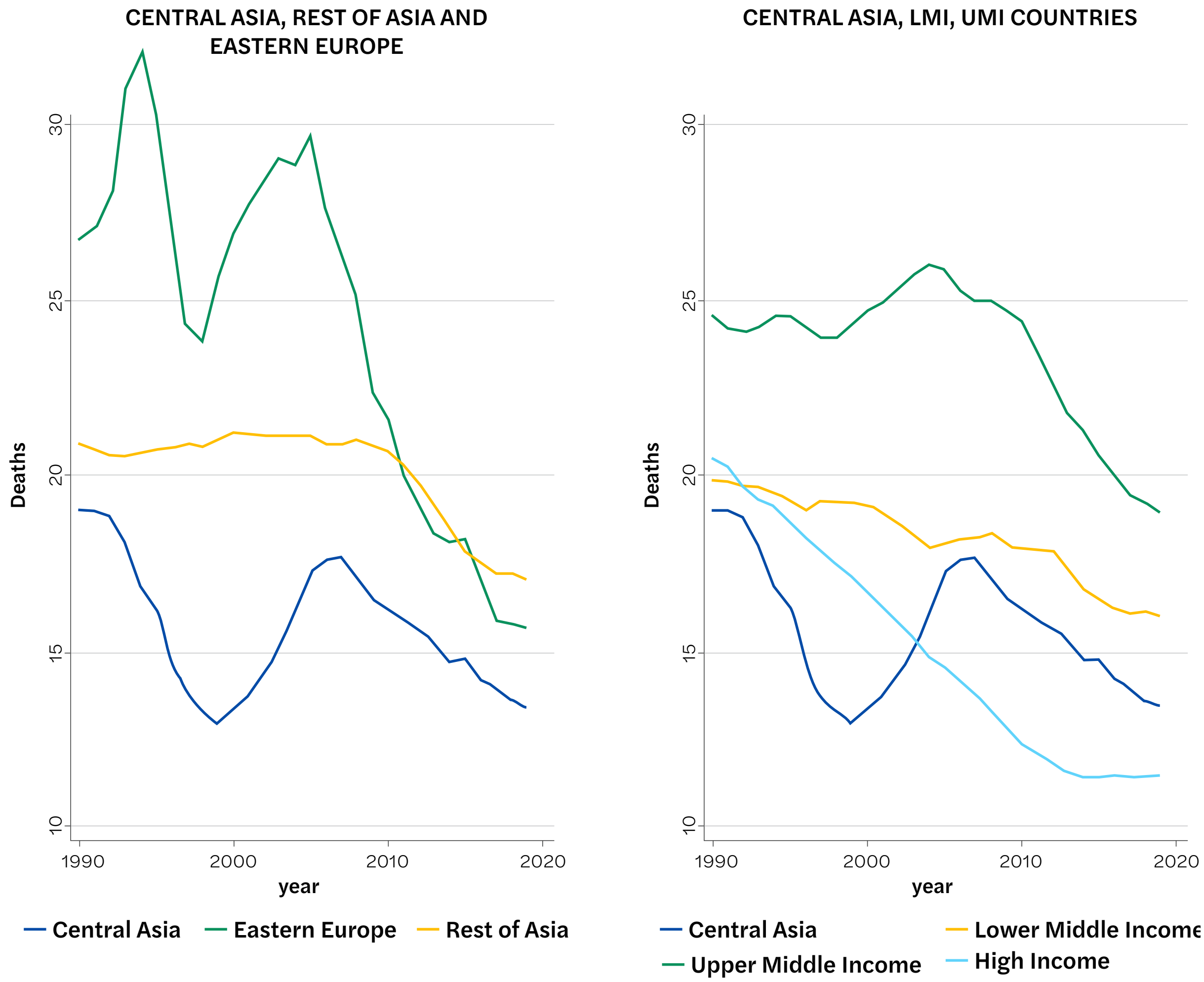


Source: GBD 2019

The four countries targeted in this study are representative of the general RTI situation in Central Asia. The number of both RTI DALYs and deaths is smaller in Central Asia than in Asia overall, and in Eastern Europe, as shown in the left panel of Figures 2.5 and 2.6, although this gap has been closing in recent years. In the rightmost panels of the figures we compare the numbers in Central Asia with those in lower middle income (LMI), upper middle income (UMI) and high income (HI) countries.[18] Central Asia has lower RTI DALYs and deaths than both the LMI and UMI, but it is higher than the HI countries. The gap with the HI countries seems to be narrowing in recent years.

18 World Bank classification

Figure 2.6 RTI Deaths per 100,000 Population, by Region and Income Classification

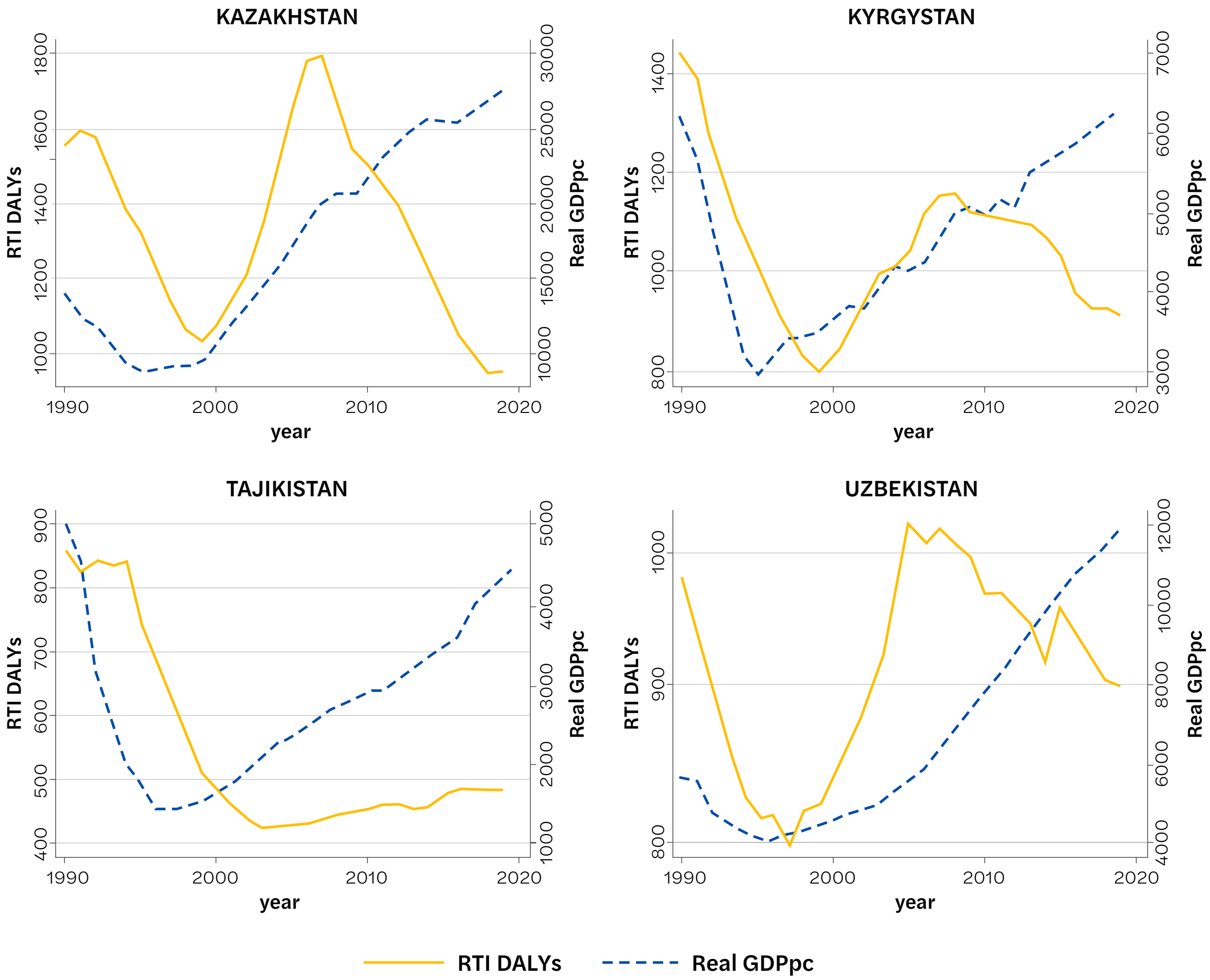


Source: GBD 2019
Note: "Eastern Europe" includes Russia, Belarus, Ukraine, Moldova, Lithuania, Estonia, and Latvia.

Figures 2.7 and 2.8 display RTI DALYs (deaths) and real GDP per capita. The GDP estimates are from the Penn World Table 10.0 (PWT 10.0), the most comprehensive, up to date, and reliable collection of macroeconomic aggregates, widely used in studies on economic growth. (Real GDP per capita is very similar in meaning to PPP-adjusted GDP per capita.) For all countries, the data clearly reveal the major economic downturn during the first years after independence, followed by sustained growth since the mid-1990s, tripling real GDP per capita in 2019, as compared to its minimum.

Figures 2.7 and 2.8 do not reveal a close correspondence between RTI DALYs (deaths) and per capita GDP. While GDP has been monotonically increasing since about 1995, RTI-specific health indicators first sharply increase and then decline (with the partial exception of Tajikistan). This evidence suggests that simple correlations are unable to tell anything about the causal effect of RTI on economic growth. The relation might even be circular, as RTI DALYs and deaths decline when better economic conditions allow people to afford better and safer cars, and there is investment in road safety (Sodikov 2021).

Figure 2.7 RTI DALYs and GDP Per Capita



Source: GBD 2019, PWT10.0

Figure 2.8 RTI Mortality and GDP Per Capita

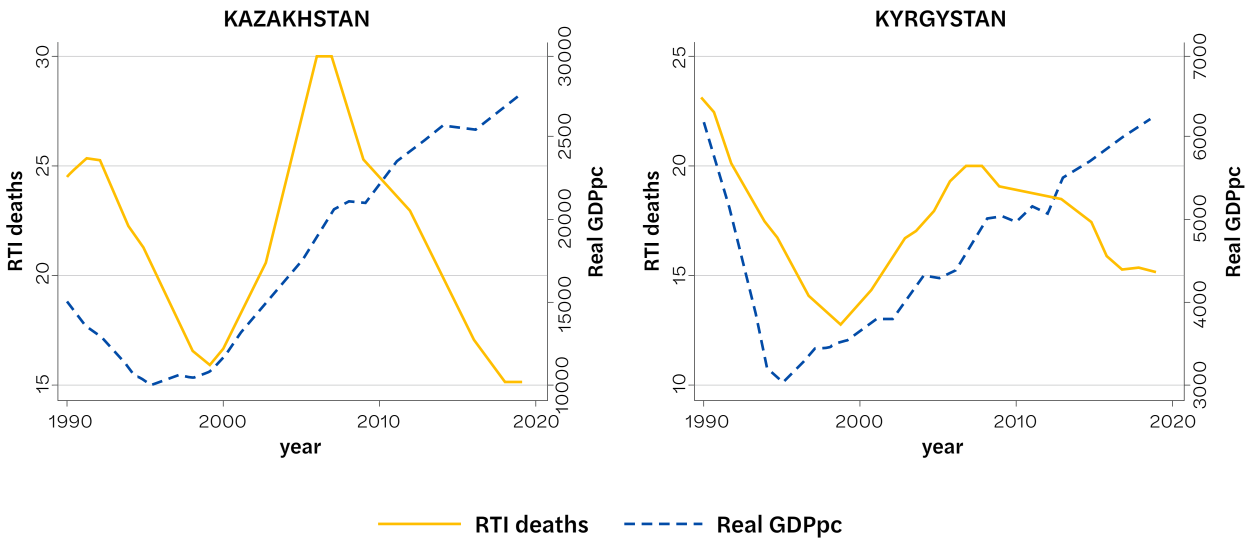
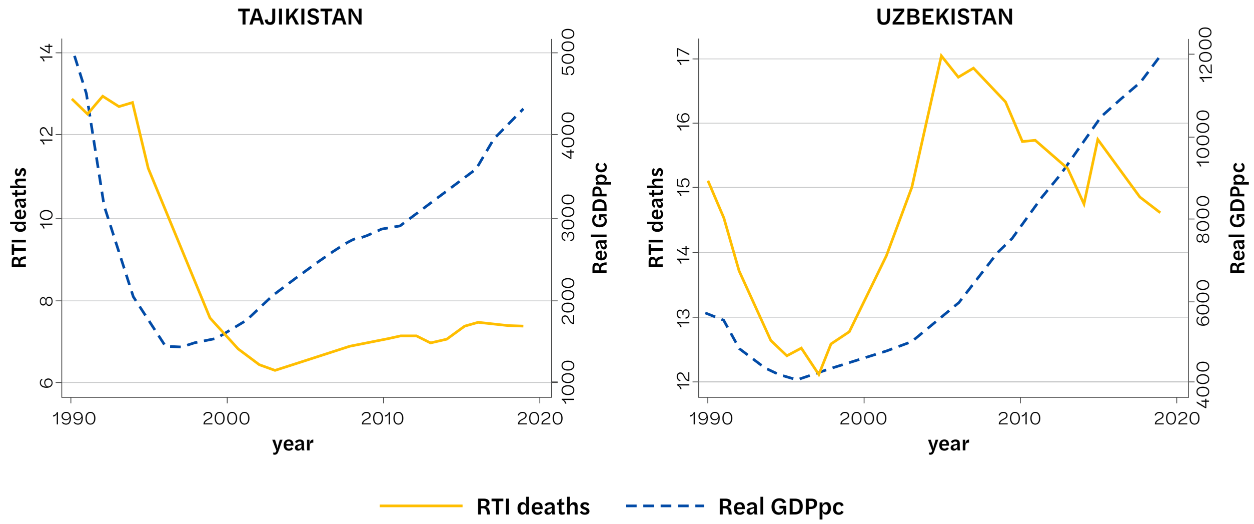


Figure 2.8 (CONT) RTI Mortality and GDP Per Capita



Source: GBD 2019, PWT10.0

HUMAN COSTS

This section presents estimates on the reduction of human costs associated with a decrease of RTI DALYs, compared to the levels of 2019.

Following the literature and international guidelines, Wijnen defines human costs as "loss of quality of life and life-years," and states, "To estimate human costs, the Willingness To Pay (WTP) approach [...] is generally regarded as the most appropriate method for calculating human costs. In the WTP approach, people are directly or indirectly asked how much money they are willing to pay for a risk reduction which enables the 'Value of a Statistical Life' (VSL) to be determined." (Wijnen 2020, 5)

Hence, for each country, the VSL is imputed. In the willingness-to-pay framework, individuals trade income for a marginal increase in their life expectancy. This is because individuals derive utility from both income and the expected number of life-years. The maximum amount that they would be prepared to pay to obtain a given increase in life-years defines their willingness-to-pay. An analogous trade-off can be expressed in terms of income and the probability of dying.

The VSL is the amount of money corresponding to one saved life. (See Appendix C for a formal presentation and derivation.) An example may be useful here: consider a reduction in the probability of dying of 1 out of 100,000. This reduction corresponds to 1 saved life in a population of 100,000 people. Now take this population and suppose that each individual is willing to pay 30 dollars to "buy" the smaller risk of death. Then the aggregate amount paid by the population to save 1 life will be 3 million dollars (i.e. $30 dollars times 100,000 inhabitants). The latter is the VSL; that is the aggregate willingness-to-pay to reduce mortality by 1 unit per 100,000 inhabitants.

The two most common strategies used to estimate willingness-to-pay are **revealed preferences**, and **contingent evaluation**. The former derives WTP from observed individual behaviors, such as choosing to equip a car with optional (and paying) safety devices, or the wage premium an employee asks to accept a hazardous job. In the latter example, individuals are directly asked about their WTP by means of questionnaires. Subjects are asked how much they are willing to pay to reduce a given risk of a given amount, in a situation which is hypothetical but described in some detail.

Both of these strategies rest on strong assumptions. The former assumes that individuals are fully aware of the level of risk associated with the various alternatives when they take actions. The latter assumes that individuals are able to understand a hypothetical situation, appreciate the proposed level of risk reduction, and are not influenced by the very fact of being asked these questions.

Estimating the VSL requires extensive microdata, which often exists in high-income countries, but much less so in LMICs. A large number of studies deal with the US, where data availability is maximal; and recent estimates place American VSL at $9.6 million. Viscusi (2015) and Viscusi and Masterman (2017) derived this value from a meta-analysis of VSL estimates. This estimate is very close to the values used by the U.S. Department of Transportation, the U.S. Environmental Protection Agency, and the U.S. Department of Health and Human Services.

Viscusi and Masterman (2017) offer a way to circumvent this problem. They begin by observing the strong link between income and VSL: that is, richer people are ready to pay more for a given reduction in the risk of dying than the poor are. The same observation applies to countries: in richer countries the VSL is larger than in poorer countries. Hence, they propose an empirical rule based on a cross-country regression to impute the VSL starting from a country's Gross National Income (GNI), and anchoring it to the US's VSL and GNI.

This strategy has been adopted here, first to update the US VSL to 2019, and to impute the VSL to the four countries of interest for 2019. The results are reported in Table 2.1. The VSL ranges from $1.4million in Kazakhstan to $163,000 in Tajikistan.[19] The positive relationship with GNI per capita is evident by comparing columns (1) and (3).

Estimates are sensitive to the level taken by the key parameter estimated by Viscusi and Masterman, namely the income elasticity of the VSL. This parameter tends to be smaller in richer countries and larger in poorer countries. For instance, it is 0.52 in the US, while it is as large as 2.5 in the poorest country. Eventually, Viscusi and Masterman suggest adopting an income elasticity equal to 1.0 because, they argue, it is "tractable and because we fail to reject the hypothesis that the international elasticity is equal to 1.0 in any of our specifications" (Viscusi and Masterman 2017, 244). The estimates in Table 2.1 follow this recommendation.

The VSL is inversely correlated with income elasticity. For instance, in Kazakhstan the VSL ranges from $3.8 million with an income elasticity of 0.5, to just $68,000 with an income elasticity of 2.5. The VSL in Uzbekistan, Kyrgyzstan, and Tajikistan would be $1.7 million, $1.4 million, and $1.3 million respectively, were an income elasticity of 0.5 applied instead of the unitary elasticity that was used in Table 2.1.

To facilitate cross-country comparison, both within the region and with the US, in Column 4 of Table 2.1 VSL estimates are adjusted for purchasing power parity (PPP), multiplying Column 3 by the conversion factor derived by the World Bank for 2019. The PPP-adjusted VSL is measured in international dollars and is directly comparable with the cost-of-illness estimates discussed in Chapter 1. The PPP-adjusted VSL turns to be between three and four times larger than the corresponding unadjusted estimates.

Table 2.1 also reports HALE for 2019, provided by the GBD study. HALE corresponds to the years lived in good health, counting for a fraction of the years lived with disability. It is then possible to compute the value of one year lived in good health by dividing the VSL by the HALE. This ratio is referred to as VSLY, Value of a Statistical Life-Year (lived in good health). VSLY ranges from $11.012 in Tajikistan to $61.685 in Kazakhstan.

19 The VSL for Kazakhstan is significantly larger than the estimates of Wijnen (2021), which are obtained from contingent evaluation questionnaires and range between 0.596m and 0.872m. The corresponding figures in Viscusi and Masterman (2017), which refer to 2015, are $1.96 million in Kazakhstan, $0.37 million in Uzbekistan, and about $0.2 million in Kyrgyzstan and Tajikistan.

Table 2.1. The Value of Statistical Life and the Value of a Statistical Life-Year

	(1) GNI PER CAPITA 2019	(2) PPP GNI PER CAPITA 2019	(3) VSL 2019	(4) VSL 2019 PPP ADJUSTED	(5) HALE	(6) VSLY (= VSL 2019 PPP ADJ / HALE)
Kazakhstan	8,820	22772	1.392m	3.896m	63.16	61,685
Kyrgyzstan	1,240	4865	0.196m	0.781m	64.93	12,028
Tajikistan	1,030	3614	0.163m	0.681m	61.84	11,012
Uzbekistan	1,800	6652	0.284m	1.208m	60.88	19,842

Note: US VSL in 2019 is $9.883 million. US GNI per capita in 2019 is $59,431.

The second step is that of assessing the value of a permanent reduction of RTI DALYs by 10 percent, compared to the level registered in 2019. The annual benefit of such a reduction is the product of the saved DALYs (Column 2 of Table 2.2) by the VSLY (Column 1 of Table 2.2). This corresponds to a proportion of the PPP-adjusted GDP, which ranges from 0.14 percent in Tajikistan to 0.30 percent in Kazakhstan (Column 4). The NPV of the stream of annual benefits from 2019 to 2048 (a 30-year period), discounted at 2 percent per year, corresponds to 3.2 percent of the 2019 PPP GDP in Tajikistan, 3.6 percent in Uzbekistan, 4.7 percent in Kyrgyzstan, and 6.9 percent in Kazakhstan.

Table 2.2. The Effect of Reducing DALYs by 10 Percent

	(1) VSLY 2019 (INT$)	(2) RTI DALYS SAVED (10% OF 2019 LEVEL)	(3) ANNUAL BENEFIT (INT$)	(4) ANNUAL BENEFIT/ GDP 2019	(4) NPV PERMANENT REDUCTION OF RTI DALYS BENEFIT / GDP 2019
Kazakhstan	61,685	21,417	1321m	0.30%	6.9%
Kyrgyzstan	12,028	5,552	67m	0.20%	4.7%
Tajikistan	11,012	3,798	42m	0.14%	3.2%
Uzbekistan	19,842	24,798	492m	0.15%	3.6%

Note: The discount rate is 2 percent. The annual benefits would be proportionally higher, if reductions of RTI DALYs were more pronounced.

If the four countries managed to gradually reduce RTI DALYs by 50 percent in 10 years (between 2019 and 2029), and they maintained the achieved level thereafter, a goal which resounds with that of SDG 3.6, the NPV of this policy would be equal to 26 percent of the 2019 PPP-adjusted GDP in Kazakhstan, 18 percent in Kyrgyzstan, 12 percent in Tajikistan, and 14 percent in Uzbekistan.[20]

It is also worth computing the benefits of avoiding a road accident in terms of saved human costs. Based on administrative sources, the number of registered accidents by year is obtained, to then compute the average ratio ρ = RTI DALYs / Road Accidents between 2015 and 2019, by country. The corresponding figures are presented in Table 2.3. The ratios are quite divergent: around 10 DALYs per accident in Kazakhstan and

20 As for the previous policy, we consider the 30-year period between 2019 and 2048, and a discount rate of 2 percent.

Kyrgyzstan, and more than 33 in Tajikistan and Uzbekistan. In all of the countries, however, the figures appear high and suggest that only severe accidents, that is, those with serious injuries or fatalities, are reported to the authorities. To err on the side of prudence, the lowest value of this ratio was assigned to all four countries. Subsequently, the benefit per accident avoided was computed by multiplying ρ by VSLY.

Avoiding a major road accident allows savings of as much as $582,206 in Kazakhstan, where the VSLY is the highest; it would be $187,308 in Uzbekistan, $113,544 in Kyrgyzstan, and $101,953 in Tajikistan, where the VSLY is the lowest.

Table 2.3: Benefits of Avoiding a Road Accident (2015-19)

	(1) ρ =RTI DALYS/ ROAD ACCIDENTS	(2) ASSIGNED ρ	(3) BENEFIT PER ACCIDENT AVOIDED
Kazakhstan	10.55	9.44	582,306
Kyrgyzstan	9.44	9.44	113,544
Tajikistan	33.54	9.44	103.953
Uzbekistan	34.89	9.44	187,308

DYNAMIC MACROECONOMIC COSTS OF RTI

This section is devoted to assessing the macroeconomic benefit of reducing RTI DALYs. As mentioned in the introduction to this chapter, this evaluation adds a dynamic component to the list of socioeconomic costs attributable to RTI, which have not been sufficiently considered in previous studies. ***While the costs of treatment, loss of potential production, property damage, and administrative costs are static concepts that capture the loss of resources associated with road crashes, this new approach focuses on how such loss impacts the future evolution of the economic system, and prospective economic development.***

The loss of labor and human capital affects firms, which have to hire and train new workers. The probability of RTI is taken into account by individuals in their saving strategies and investments in physical, financial, and human capital, because a higher probability of RTI lowers investment returns by reducing survival probability and life expectancy. In turn, this affects interest rates and the price of skills and competencies. The fact that RTI prevalence is larger in the working-age population strengthens this argument. Several other mechanisms are likely to be at work too, depending on the actions that both firms and individuals take to insure against the risk of RTI.

This analysis will evaluate the result of all of these mechanisms taken together, that is, the reaction of the economic system to a variation in RTI DALYs. A detailed disentangling of the effects of each mechanism is beyond the scope of the present research, and may be hard to achieve without complex structural modeling.

This analysis builds upon and arguably improves upon an analogous exercise that was carried out recently as part of the Bloomberg Initiative (World Bank 2017). Improvements include an updated data set covering the period from 1990 to 2019; a novel strategy for addressing the problem of the mismeasurement of RTI DALYs and mortality; and another novel strategy borrowed from the recent Rocco et al. (2021) study to address the problem of unobserved confounders, drawing on recent advances in econometric methodologies. Details of the model specification are available in Appendix C.

The data set used covers 136 countries, which were followed from 1990 to 2019. It includes country-level data from many sources, such as the Penn World Tables, the World Development Indicators, the Global Burden of Diseases, Freedom House, the updated Barro-Lee education dataset, the World Values Survey, and Gallup et al. (1999) data. Only countries for which one or more variables are missing were excluded.

Economic performance is measured by the percentage change in real GDP per capita between 1990 and 2019. PPP-adjusted GDP per capita is provided by the Penn World Table 10.0.[21] The main variable of interest is RTI DALYs per 100,000 individuals in the working-age population, estimated from the GBD study. RTI mortality in the working-age population was also used, from the same source.

This estimation procedure is designed to avoid directly using RTI DALYs or RTI mortality, since they can have significant problems of mismeasurement due to misclassification or underreporting of road crashes. Rather it uses all-cause DALYs and non-RTI DALYs (that is, the combined number of DALYs from all causes other than RTI), and then indirectly derives the effect of RTI DALYs on long-run economic growth.

The identification of causal effects rests on techniques of so-called partial identification. Details are available in Rocco et al. (2021). For the purposes of this report it suffices to say that the purpose of the analysis is that of finding informative bounds for the true effects of all-cause and non-RTI DALYs. Derivation and technical details can be found in the Appendix C.

Our results suggest that reducing 2019 RTI DALYs by 10 percent would increase economic growth from 2019 to 2048 (a 30-year period) of about 0.55 percentage points on average. This additional growth would also imply a higher per capita income in 2048 of $140 in Kazakhstan, compared to the level that would be observed if RTI DALYs remained unchanged ($32.3 in Kyrgyzstan, $11.0 in Tajikistan, and $55.4 in Uzbekistan.)

If this additional income were to accrue linearly over the period 2019-48, the corresponding NPV would be 5.4 percent of 2019 real GDP per capita in Kazakhstan; 5.5 percent in Kyrgyzstan; 2.7 percent in Tajikistan; and 4.9 percent in Uzbekistan, as reported in Table 2.4.[22]

Table 2.4. Macroeconomic Effect of Reducing RTI DALYS in the Working-Age Population by 10 Percent

	(1) ADDITIONAL REAL GDP PER CAPITA IN 2048	(2) NPV OF THE TOTAL ADDITIONAL INCOME BETWEEN 2019 AND 2048	(3) REAL GDP PER CAPITA 2019	(4) (2)/(3)
Kazakhstan	140.8	1503.6	27643	5.4%
Kyrgyzstan	32.3	345.0	6314	5.5%
Tajikistan	11.0	117.2	4398	2.7%
Uzbekistan	55.4	592.1	11992	4.9%

Note: The annual discount rate adopted to compute the NPV is 2 percent.

21 Specifically, we used the real GDP per capita in constant 2017 prices and constant US dollars. This allowed us to measure income variation net of inflation, and different purchasing power across the countries.

22 An annual discount rate of 2 percent is applied.

Using simple calculations, we can evaluate the benefits of alternative policy scenarios; for example, a scenario where RTI DALYs progressively reduce by 50 percent by 2029, and maintain the achieved level thereafter until 2048. In this case, the benefits would amount to 4.1 times the values reported in Column 4 of Table 2.4. Such aggressive policy intervention would imply macroeconomic benefits of 22.1 percent of 2019 GDP in Kazakhstan, 22.5 percent in Kyrgyzstan, 11.7 percent in Tajikistan, and 20.0 percent in Uzbekistan.

Additional estimates also capture the effect of reducing RTI mortality in the working-age population by 10 percent from the level observed in 2019. In this case, the average effect of this reduction would be equal to an additional 0.45 percentage point income growth in the 30-year-long period from 2019 to 2048. This amounts to an additional annual income at the end of the period of $116.6 in Kazakhstan, $27.7 in Kyrgyzstan, $8.7 in Tajikistan, and $47.2 in Uzbekistan. Following the same procedure used for RTI DALYs, these figures correspond to a benefit greater than 4 percent of 2019 GDP per capita in Kazakhstan, Kyrgyzstan, and Uzbekistan, and about 2 percent in Tajikistan (Table 2.5).

In such a case the aggressive policy of halving RTI mortality by 2029 compared to its level in 2019 would provide benefits 4.1 times larger than those reported in Table 2.5.

Overall, the macroeconomic effect of reducing RTI by 10 percent is comparable to the saved human costs that we have assessed in the section on "Human Costs." Despite the individual advantage being relatively small compared to the value of one year of life saved (VSLY), the macroeconomic effect affects the entire population, while human costs are concentrated on the relatively few people who are involved in road crashes.

Along with the human costs, the dynamic macroeconomic costs emerge as a leading component of the economic burden of RTI morbidity and mortality. Human costs and macroeconomic costs are not alternative or incompatible concepts: rather, they complement each other to provide a more correct representation of the economic losses associated with RTIs.

Table 2.5. Macroeconomic Effect of Reducing RTI Mortality in the Working-Age Population by 10 percent

	(1) ADDITIONAL REAL GDP PER CAPITA IN 2048	(2) NPV OF THE TOTAL ADDITIONAL INCOME BETWEEN 2019 AND 2048	(3) REAL GDP PER CAPITA 2019	(2)/(3)
Kazakhstan	116.6	1245.4	27643	4.5%
Kyrgyzstan	27.7	296.2	6314	4.7%
Tajikistan	8.7	92.6	4398	2.1%
Uzbekistan	47.2	504.1	11992	4.2%

Note: The annual discount rate adopted to compute the NPV is 2 percent.

CHAPTER 3:
EVIDENCE-BASED INTERVENTIONS TO TACKLE RTIS

This section moves beyond estimation of the economic costs of inaction (and/or the benefits of action), to discuss what could be done to achieve the desired reduction in road traffic injuries (RTIs). Our discussion is based on a review of the existing evidence on the effectiveness and cost-effectiveness of RTI interventions and policies, with a focus on low- and middle-income countries (LMICs). Alongside – and at least partly building on – this evidence as well as the more frequently available high-income country evidence, there are general recommendations as to what a successful RTI response should ideally entail. This is for instance described in the latest Disease Control Priorities (DCP) edition, in Volume 7 on Injury Prevention and Environmental Health. Upon acknowledging the absence of a "blueprint" for road safety, the chapter by Bachani et al. (2017) outlines what may be seen as a broad consensus on a set of principles for interventions, including:

- **Reduction of risk exposure** by stabilizing motorization levels, providing alternative modes of travel, and improving land-use planning practices;
- **Reduction of risk factors directly related to crash causation**, such as speeding, drinking and driving, using unsafe vehicles on unsafe roads (with inadequate safety features for the traffic mix), and failing to enforce road traffic safety laws effectively;
- **Reduction of the severity of injuries** by mandating and enforcing the use of seat belts, child restraints, and helmets, as well as by improving road infrastructure and vehicle design to protect all road users; and
- **Improvement of post-crash outcomes** through the use of appropriate and life-saving measures from the scene of the crash all the way through to rehabilitation services.

Additional general recommendations are also set out in the UN's strategy on The Decade of Action for Road Safety 2011–20, which adopts a systems approach to addressing the burden of RTIs, and proposes five pillars: Road Safety Management; Safer Roads and Mobility; Safer Vehicles; Safer Road Users; and Post-Crash Care (United Nations Road Safety Collaboration 2010).

This chapter provides a brief summary, and some examples of the existing evidence base that may serve as a useful basis to inform policy decisions in Central Asian countries. Detailed policy recommendations for each specific country would require a more focused epidemiological and policy analysis, which is beyond the scope of the present report. The first section of the chapter starts by reviewing what, from an economic perspective, would be particularly desirable to have: evidence of cost-effectiveness that can inform priority-setting from within limited budgets. As this evidence is scarce globally, and even more scarce in LMICs, the second section complements this summary with a brief account of the evidence base in terms of effectiveness.

COST-EFFECTIVENESS OF RTI INTERVENTIONS IN LOW- AND MIDDLE-INCOME COUNTRIES

The DCP3 project, as well as several recent reviews, have scrutinized the available evidence for the cost-effectiveness of RTI interventions in the context of LMICs, but they have found only very few such studies. The DCP3 chapter authored by Watkins et al. (2017) highlights one quasi-experimental study by Bishai et al. (2008), which assessed a traffic enforcement program in Uganda. This intervention was about reducing speeding, and the study demonstrated that a reduction in fatal crashes could be achieved at a cost of $944 per death averted. Using simulation modeling, research in Thailand (Ditsuwan et al. 2013) evaluated the cost-effectiveness of several hypothetical interventions for RTIs, including checkpoints, media campaigns, and breath-testing, alone or in combination. All of these interventions turned out to be very cost-effective when compared to the “do-nothing” scenario, and even cost-saving when the treatment costs averted were included in the incremental cost-effectiveness ratio calculations (Ditsuwan et al. 2013). Watkins et al. also extracted the program costs of the interventions, and found RTI prevention interventions in both Thailand and Uganda to cost less than $1 per capita.

Banston & Mytton (2017) covered some of the same evidence in their RTI cost-effectiveness review, but added one wide-ranging modeling study by Chisholm et al. (2012), which estimated the population costs and the effects of a selected set of enforcement strategies for reducing the burden of RTIs in developing countries for two WHO subregions of the world: countries in Sub-Saharan Africa with very high adult and high child mortality (AfrE); and countries in Southeast Asia with high adult and high child mortality (SearD). (See Table 3.1 for details of the estimates by study and by specific interventions.)

Based on the Banston & Mytton review, five studies covering nine interventions were included in Table 3.1. Overall, the cost-effectiveness of RTI interventions in LMICs ranged from $4.14 per disability-adjusted life-years (DALYs) that were averted by building speed bumps at the most dangerous junctions studied (those that that had caused 10 percent of junction deaths in the area) to $3,403 per DALYs averted through legislation and enforcement of helmet use by motorcyclists in the WHO Sub-Saharan Africa region. While this is encouraging, the authors conclude that the evidence for the cost-effectiveness of interventions to prevent RTIs in LMICs is limited, particularly for children, young people, and vulnerable road users. They also call for the evaluation of a larger set of possible RTI interventions in a variety of LMIC settings in order to develop the evidence base for effective traffic injury prevention programs.

Table 3.1: Evidence for Cost-Effectiveness of RTI Interventions in LMICs

AUTHOR, YEAR	ECONOMIC CHARACTERISTICS	INTERVENTION	COSTS OF INTERVENTION (ANNUAL)	COST PER DALYS AVERTED (YEAR 2013 US$)	REPORTING OF COST-EFFECTIVENESS
Bishai and Hyder (2006)	Perspective: Governmental# & Societal Time horizon: 1 year Discounting: 3% & 6% Sensitivity analyses: Not stated Currency: Local currency converted to US$ (2001)	Improved enforcement of traffic codes	$96,807	$64 ($81) at 3% $101 ($128) at 6%	Cost-effective
		Building speed bumps at high-risk intersections	$165	$3.26 ($4.14) at 3% $5.12 ($6.50)at 6%	Very cost-effective[e]
		Bicycle helmet legislation and enforcement	$265,000	$107 ($136) at 3% $170 ($216) at 6%	Cost-effective[f]
		Motorcycle helmet legislation and enforcement	$257,500	$467 ($593) at 3% $769 ($977) at 6%	Cost-effective[f]
Bishai et al. (2008)	Perspective: Police department Time horizon: Not stated Discounting: 3% Sensitivity analyses: Sensitivity of results compared to a discount rate of 10% Currency: Ugandan Shillings converted to US$ (2005)	Increasing traffic safety enforcement	$72,000	$27 ($31)*ф	Very cost-effective
Chisholm et al. (2012)	Perspective: Not stated, but societal/ governmental (inferred) Time horizon: 10 years Discounting: 3% Sensitivity analyses: One-way sensitivity analyses and probabilistic uncertainty analysis Currency: International dollars ($Int) for the year 2005§	Enforcement of speed limits (via mobile speed cameras)	$Int0.28a,b $Int0.13a,c	$Int1,668 ($849)[b] $Int1,589 ($588)c	Cost-effective b; Very cost-effective c
		Drink-drive legislation and enforcement (via breath-testing campaigns)	$Int0.26a,b $Int0.12a,c	$Int2,236 ($1,139)[b] $Int2,731 ($1,011)c	Cost-effective b,c
		Legislation and primary enforcement of seat belt use in cars (drivers and passengers)	$Int0.23a,b $Int0.07a,c	$Int4,579 ($2,332)[b] $Int2,502 ($927)c	Cost-effective b,c
		Legislation and enforcement of helmet use by motorcyclists (all riders)	$Int0.13a,b $Int0.10a,c	$Int6,683 ($3,403)[b] $Int1,696 ($628)c	Cost-effective b,c
		Legislation and enforcement of helmet use by bicyclists (aged <15 years)	$Int0.14a,b $Int0.07a,c	$Int1,233 ($628)[b] $Int3,678 ($1,362)c	Very cost-effective b; Cost-effective c
		(i) Speed limits + drink-driving	$Int0.40a,b $Int0.18a,c	$Int1,406 ($716)[b] $Int1,439 ($532)c	Cost-effective b,c
		(ii) Seatbelt use + motorcycle helmet use	$Int0.38a,b $Int0.20a,c	$Int5,472 ($2,786)[b] $Int2,239 ($828)c	Cost-effective b,c
		(iii) Speed limits + drink-driving + seat belt use	$Int0.49a,b $Int0.20a,c	$Int1,483 ($756)[b] $Int1,305 ($484)c	Cost-effective b,c
		(iv) Speed limits + drink-driving + motorcycle helmet use	$Int0.40a,b $Int0.23a,c	$Int1,333 ($679)[b] $Int1,237 ($458)c	Cost-effective b,c

Table 3.1 (CONT): Evidence for Cost-Effectiveness of RTI Interventions in LMICs

AUTHOR, YEAR	ECONOMIC CHARACTERISTICS	INTERVENTION	COSTS OF INTERVENTION (ANNUAL)	COST PER DALYS AVERTED (YEAR 2013 US$)	REPORTING OF COST-EFFECTIVENESS
		(v) Drink-driving + seat belt use + motorcycle helmet use	$Int0.50a,b $Int0.26a,c	$Int2,725 ($1,387)[b] $Int1,919 ($710)c	Cost-effective b,c
		(vi) Speed limits + seat belt use + motorcycle helmet use	$Int0.50a,b $Int0.26a,c	$Int2,116 ($1,077)[b] $Int1,466 ($543)c	Cost-effective b,c
		(vii) Speed limits + drink-driving + seat belt use + motorcycle helmet use	$Int0.50a,b $Int0.26a,c	$Int1,428 ($727)[b] $Int1,181 ($437)c	Cost-effectiveb,c
		(viii) Speed limits + drink-driving + seat belt use + motorcycle helmet use + bicycle helmet use	$Int0.64a,b $Int0.33a,c	$Int1,376 ($700)[b] $Int1,382 ($511)c	Very cost-effective b,c
Ditsuwan et al. (2013)	Perspective: Health sector Time horizon: 1 year Discounting: 3% Sensitivity analyses: Multivariate probabilistic sensitivity analysis Currency: Thai baht (2004)¤	Selective Breath Testing (SBT)	345 million baht	13,000 baht ($986)	Very cost-effective
		Random Breath Testing (RBT)	345 million baht	14,300 baht ($1,085)	Very cost-effective
		Mass media campaign	179 million baht	10,300 baht ($781)	Very cost-effective
		SBT + mass media	523 million baht	12,700 baht ($963)	Very cost-effective
		RBT + mass media	523 million baht	13,500 baht ($1,024)	Very cost-effective
Stevenson et al. (2008)	Perspective: Societal Time horizon: 1 year Discounting: Not stated Sensitivity analyses: Not stated Currency: Chinese Yuan (¥) converted to US$ (2006)d	Comprehensive seat belt interventions (enhanced police training and enforcement, social marketing, and health education)	¥1,720,577g	¥3,246 ($1,049)	Very cost-effective

Source: Banston & Mytton (2017)
Notes: DALYs: Disability-Adjusted Life Years

For improved enforcement of traffic codes only
***** At a 10% discount the cost per discounted life-year saved approximately doubled
ɸ cost per life year saved
§ For African sub-regions, $Int1=US$0.44; South East Asia, $Int1 = US$0.32
¤ US$1 = 41 Thai baht for the year 2004
a Cost per capita (i.e. millions of international dollars ($Int) per million population)
b AfrE: WHO Sub-Saharan African region
c SearD: WHO Southeast Asia region
d Costs presented in the cost-effectiveness analysis are expressed in 2006 Chinese yuan (¥), with incremental cost-effectiveness ratios expressed in US$
e If constructed at the most dangerous junctions (those that cause at least 10 percent of j unction deaths)
f Cost-effective in China
g Net costs of intervention: obtained by subtracting the total intervention cost with cost savings (¥3,124,726 - ¥1,404,14)

More recently, Symons et al. (2019), have added to the evidence on "value-for-money" of RTI interventions in LMICs with a global sampling of 75 LMICs, and with a focus on people aged 10-24 years. Starting with the identification of "key interventions" backed by published evidence, from which they extracted and estimated the costs and health impacts, they incorporated these into a modeling framework to assess the reduction in deaths and serious injuries achieved from 2016 to 2030 as compared to the base case. Building on this, they derived benefit-cost ratios for each of the interventions.

The three key interventions, for which they argue a "broad consensus" exists in the literature, are speed enforcement, alcohol enforcement, and safer road infrastructure. Additional interventions were considered specifically for motorcycle riders (helmets); occupants of motor vehicles (seat belts); and young drivers (a graduated licensing scheme). Table 3.2 presents the effectiveness of each of these interventions, as reported in at least one published paper.

Table 3.2: Range of Effectiveness of Interventions

INTERVENTION	MEASURE OF EFFECTIVENESS	EFFECTIVENESS SUMMARY RANGE (%)
Seat belts	Wearing seat belt	Fatalities 7-65 Injuries 18-83
Helmets	Wearing helmet	Fatalities 20-48 Injuries 18-72
Alcohol enforcement	Modern constraints on alcohol use on roads	Fatalities 3-48 Injuries 3-48
Speed enforcement	Systematic speed limit enforcement Injury severity reduction due to percentage speed reduction Injury severity reduction due to speed reduction	• Fatalities 17-25 • Injuries 14-56 • Injuries 6-50
Graduated licensing scheme (GLS)	Implementation of GLS scheme	Fatalities 31-57 Crash rates 4-43
Investment in safer roads		Injury accidents 7-20

Source: Symons et al. (2019)

Symons et al. then proceeded to model a scenario in which all six interventions were jointly implemented in the 75 countries. Assigning costs and effects to this package of interventions, and translating them into monetary terms while assuming a 3 percent discount rate, they estimated the benefit-cost ratios (BCRs) overall for all countries as well as by country subgroup, based on income. The resulting overall BCR is estimated at 7.6 and appears fairly uniform across country groupings. This increases to 9.9 percent for a scenario up to 2050. In the authors' judgment, despite the significant associated uncertainty around these estimates, "...these are strong BCRs by any standards" (Symons et al. 2019, S41).

The global analysis by Moyer et al. (2017) similarly supports the notion of a favorable return-on-investment to be reaped from effective RTI prevention at scale, as they conclude that "such investments are likely to pay for themselves as the economic returns from effective intervention accumulate" (Moyer et al. 2017, 755).

EVIDENCE OF THE EFFECTIVENESS OF ROAD TRAFFIC INJURY INTERVENTIONS IN LOW- AND MIDDLE-INCOME COUNTRIES

Evidence on the effectiveness of road traffic injury (RTI) interventions in an LMIC setting well exceeds that on cost-effectiveness, but this also remains underresearched when compared to the evidence from high income countries (HIC), as highlighted, for instance, in the DCP3 chapter on RTIs (Bachani et al. 2017).[23] However, this source still provides a useful starting point to obtain an overview of what is known about the effectiveness of RTI interventions specifically in LMICs. Bachani et al. describe the set of interventions that have proved effective in an HIC context and that have at least been evaluated to some extent--either empirically, or using a modeling approach--in an LMIC context. Appendix D Table D1 reproduces a version of Bachani's table.

In recent years, several more reviews have been published, zooming in on either different subgroups of the population or on a subset of RTI interventions, covering LMICs specifically or as part of a global perspective. For instance, a recent scoping review by Selveindran et al. (2020) assessed the evidence on approaches in neurotrauma and RTI prevention globally, distinguishing HIC from LMIC evidence. The review identified a fairly sizable evidence base at the global level (411 publications, including 349 primary studies and 62 reviews), with the vast majority focused on HICs. Only 65 of these studies address LMICs, and they mostly cover primary prevention, focusing on road safety. Out of those studies, most were in the legislation/policy category, and the most common approach was helmet policy. Other common strategies and interventions focused on helmet use, traffic calming, road modification, and traffic policing or patrolling. The three reviews of LMIC papers described multiple interventions and strategies that included both personal and public-level approaches. These findings show that while the evidence is not abundant, there does exist nonetheless a variety of interventions for the primary prevention of RTIs in LMICs. It should be noted, however, that the authors identified a clear scarcity in papers on vehicle engineering, particularly pertaining to in-vehicle safety technology.

Staton et al. (2016) examined in more detail the existing evidence base on the effectiveness of RTI prevention in LMICs. A total of 18 articles from 11 LMICs were included in the core body of the evidence base. Of these studies, four were from Sub-Saharan Africa, ten from Latin America and the Caribbean, one from the Middle East, and three from Asia. Legislation was the most common intervention evaluated, with the best outcomes occurring when combined with strong enforcement initiatives or as part of a multifaceted approach. Because speed control is crucial to crash and injury prevention, when planning road improvement interventions in LMIC settings, the way that road improvements are likely to affect vehicle speed and traffic flow should be carefully considered.

A very recent Major World Bank effort also provides a useful assessment of "what works" (and what does not work) in terms of RTI policies (Turner et al. 2021). The report presents the policy evidence within a "Safe System" context, and provides advice concerning each of the Safe System pillars, while recognizing that evidence-based solutions must be drawn from across the pillars to produce effective road safety outcomes.[24] A core table of the report that documents the policies deemed "highly effective" based on the existing evidence base is reproduced in Table 3.3.

23 See also Selveindran et al. (2020), Staton et al. (2015), Bonnet et al. (2018), Heydari et al. (2019), Gupta & Bandyopadhyay (2020), Tupetz et al. (2020), and Salam et al. (2016).

24 The Safe System pillars are: Road Safety Management; Safe Roads; Safe Speeds; Safe Vehicles; Safe Road Users; and Post-Crash Care.

Table 3.3 Highly Effective Interventions*

ROADS AND ROADSIDES	SPEEDS	ROAD USERS	VEHICLES	POST-CRASH CARE
Integrated public transport	Traffic calming	Increased helmet-wearing rates	Seat belts	—
Barrier systems	Roundabouts	Increased seat-belt-wearing rates	Electronic Stability control	
Medians	Raised intersections	Advanced vehicle technologies		
Infrastructure solutions to support appropriate speeds	Raised crossings			
Roundabouts	Gateway treatments			
Grade separation	Lower speed limits			
Reducing risk exposure at intersections	30 km/h (20 mph) zones for pedestrians			
Pedestrian footpaths	Speed cameras			
Pedestrian crossings				

Source: World Bank Global Road Safety Facility (2021)
*Interventions producing crash reduction benefits of 30 percent or more.

Another recent review (Vecino-Ortiz et al. 2018) arguably adds particular value; in addition to reviewing the evidence of effectiveness for the five main types of unintentional injury in LMICs, it also estimates the potential number of lives saved by effective injury interventions among the poorest billion people worldwide. The set of interventions covered in this review went beyond RTI interventions, but out of the latter, the most successful interventions in preventing deaths were found to be speed enforcement (>80 000 lives saved per year) and drink-driving enforcement (>60 000 lives saved per year). (See Table 3.4 for a concise summary; and see Appendix D - Table D2 for study- and intervention-specific details.)

Table 3.4: Total Number of Potential Lives Saved Among the Poorest Billion

RTI INTERVENTIONS	NUMBER OF LIVES SAVED
Drink-driving enforcement	67,670
Traffic enforcement	39,882
Seat-belt enforcement	15,783
Helmet-use law**	328
Speed enforcement	84,287
Helmet-use enforcement	9,882

Source: Vecino-Ortiz et al. (2018)
Note : *Across 84 countries, by intervention for selected, evidence-based RTI interventions.
****Note:** For helmet-use law, only seven countries do not have a helmet-use law, hence the number of lives saved is not as large as might be expected.

The authors usefully emphasize the importance of and need for country-specific priority-setting – a challenge that cannot be met with most, if not all, of the review evidence presented in their study, and a caveat that needs to be borne in mind when distilling recommendations for the specific Central Asian countries that are the focus of this report. Specifically, Vecino-Ortiz et al. found substantial variation in the baseline levels of the variables used in their estimation—for example, the percentage of the population belonging to the poorest billion, enforcement levels, and mortality for each cause of injury. This variability reflects the need for **customized** approaches for each country when prioritizing injury interventions. As an additional limitation, the authors also note that they assumed the examined interventions to act independently of each other, while in reality there may well be synergies to be reaped from implementing *sets* of interventions when possible.

Other reviews, for example Salam et al. (2016), have focused on subgroups of the population in their global systematic review and meta-analysis of interventions for preventing unintentional injuries among adolescents. While the review found encouraging results for ***sets*** of interventions--for example, a graduated driver license, helmet use,[25] and seat belt use--the authors also concluded that the existing evidence was once again mostly from HICs, hence limiting the ability to generalize these findings for LMICs, and calling for the replication and evaluation in an LMIC context with standardized outcome measures.

Lefio et al. (2018) concentrated on the general and working population in their systematic review of interventions to reduce motor vehicle crashes and associated injuries. They found that – again, globally–the interventions that most consistently appear to reduce the incidence, morbidity, and mortality attributable to motor vehicle collisions are national policies or programs that regulate, enforce, and penalize driving under the influence of alcohol; improve driving safety and driving conditions; improve road infrastructure with the purpose of preventing collisions; and educate and penalize drivers who have a history of road violations.

Another interesting approach has been applied by Martin et al. (2018); this study is not a literature review, but a simulation exercise applied to one country from each of the regions of the WHO and World Bank country income levels. (Interestingly, from a Central Asian perspective, Uzbekistan is one such case study.) Based on the idea that delayed implementation of effective road safety policies must be considered when quantifying the avoidable part of the fatal and nonfatal injuries burden, the authors tried to assess the avoidable part of DALYs lost due to RTIs that were related to delays in implementing road safety laws in low- and lower-middle-income countries. Delays in implementation were calculated up until 2013, starting from the year mandatory use of safety belts by motor vehicle front seat occupants was first introduced worldwide (i.e. in 1972). Starting from that year, implementation delays varied from 27 years in Uzbekistan to 41 years in Bolivia (which still had no seat belt law as of 2013). The total absolute numbers of DALYs lost due to RTIs reached 8,462,099 in Nigeria, 7,203,570 in Morocco, 4,695,500 in Uzbekistan, 3,866,391 in Cambodia, 3,253,359 in Bolivia, and 3,128,721 in Sri Lanka. Using effectiveness estimates ranging from 3 to 20 percent reduction, the avoidable burden of RTIs for automobile occupants was highest in Uzbekistan (the avoidable part from 1.2 to 10.4 percent) and in Morocco (avoidable part from 1.5 to 12.3

25 The utility of helmet legislation for the primary prevention of road traffic accident–related traumatic brain injuries in younger populations was also confirmed in the global review by Du et al. (2020). The authors also emphasize that not all helmet laws are equal, and that a comprehensive, context-specific approach is critical for success, especially in LMICs.

percent).[26] In countries where users of public transport and pedestrians were the most affected, the avoidable parts ranged from 0.5 to 4.4 percent (Nigeria) and from 0.5 to 3.4 percent (Bolivia). The burden of RTIs affected motorcyclists in Sri Lanka and Cambodia the most, where the avoidable parts were less than 2 percent in both countries. In all of the selected countries, the burden of traffic injuries affected young men (15-34) the most (about 80 percent). According to Martin et al., such results can be used to convince countries to avoid delaying the provision of better protection for road users.

26 Martin et al. (2018) estimated the "avoidable burden" of DALYs on the basis of estimates of the effectiveness of seat belt laws on fatal and nonfatal RTIs combined, as extracted from published international reviews of evidence.

CHAPTER 4: CONCLUSION AND RECOMMENDATIONS

This report has focused primarily on assessing selected dimensions of the economic consequences of road traffic injuries (RTIs), as applied specifically to four Central Asian countries. Understanding the economic magnitudes involved in RTIs is important, first of all as a way of underlining the notion that RTIs matter not "only" because of the associated burden of mortality and morbidity, but also from an economic perspective. Such estimates also have the potential to feed into – and influence – cost-benefit calculations of policies designed to tackle RTIs, as they tend to add previously underappreciated economic benefits to the value-for-money assessments.

In Chapter 1 we estimated various dimensions of the health care costs attributable to RTIs, both at the health system and at the individual/household levels. Our study shows that RTIs not only impose a serious disease and mortality burden, including protracted hospitalizations and permanent medical impairment; they also entail a considerable financial burden for the health care system overall**.** In these four Central Asian countries the total health care costs of the estimated RTIs that occurred in 2016 amounted to Int$95 million, ranging from Int$2.8 million in Tajikistan to Int$49.3 million in Kazakhstan.

The distribution of health care costs is skewed, with admitted road crash casualties for inpatient acute care and early or late consequences of injury accounting for more than 80 percent of the costs in all four countries we studied. Prehospital emergency care registered less than 2 percent of aggregate health care costs from RTIs in Kyrgyzstan, Tajikistan, and Uzbekistan, since this type of care is rarely used within the crash casualty pathway in these countries. The average share of fatalities in total health care costs was fairly low, ranging from 1.4 percent in Kyrgyzstan to 7.6 percent in Tajikistan. These values suggest that a large number of deaths (approximately 70 percent) occurred at the crash scene, before any intervention by the health care system.

While there are no obvious traffic-injury-related expenditure level targets, the observed expenditure levels should indicate to governments that little or no progress can be made in terms of service coverage and financial protection for crash casualties when spending levels are low. ***The cost estimates in this study, and the existing evidence on the chain of care for crash casualties suggest a likely case for redistributing current expenditures related to RTIs, by shifting funding from inpatient care to prehospital emergency care. However, reallocation of funding for post-crash care and the associated reorganization this would entail should be approached from a holistic perspective, taking into account the balance and coordination between all types of care.***

These cost estimates indicate the potential scope for economic cost savings if both deaths and injuries from road crashes could be substantially reduced. Chapter 1 provided a scenario analysis to estimate the likely cost savings of three RTI reduction scenarios. The cumulative costs to be avoided by the health care system by 2025 in the case of the "median" scenario would amount to Int$28.1 million for Kazakhstan, Int$5.2

million for Kyrgyzstan, Int$1.9 million for Tajikistan, and Int$22.5 million for Uzbekistan. This would correspond to a decrease in the share of current health expenditures (CHE) by 56 percent in Kazakhstan, 62 percent in Kyrgyzstan, 65 percent in Uzbekistan, and 67 percent in Tajikistan. Changes in injury patterns toward a reduction in the severity of injuries should also be considered as an integral part of the potential overall reduction of injury rates, since this would also help to decrease health care costs.

Although these estimates appear to be substantial, in order to assess how much these expenditures can realistically be avoided, the effects of specific post-crash interventions must be taken into account. Substantial research and the development of various road safety interventions over the past three decades have documented the spectrum of post-crash interventions that are in principle available to prevent death and limit the severity of injury (WHO 2015). Central Asian countries should consider the appropriateness, effectiveness, and cost of these options, in the context of their local and national situations.

In Chapter 2 we presented a macro-level perspective, by estimating the human costs and the effect of RTIs on macroeconomic development in the four countries we studied. The human costs have been proven to be by far the largest cost component in an analysis carried out in both rich and poor countries (Wijnen and Stipdonk 2016). The results presented in this study show that permanently reducing RTI-attributable DALYs in the working-age population by 10 percent would save human costs in an amount equivalent to a significant fraction of the 2019 GDP of these countries, ranging from 2.7 percent in Tajikistan to 6.4 in Kazakhstan. The effect of RTIs on the prospects for the economic development of the countries is almost as large: the same hypothetical reduction in RTI-attributable DALYs would significantly enhance economic growth; by 2048 per capita GDP would be expected to be Int$140 higher in Kazakhstan than it would be if RTI DALYs had remained unchanged; in Kyrgyzstan Int$32.3 higher; in Tajikistan Int$11.0 higher; and in Uzbekistan Int$55.4 higher. This implies a total additional income ranging from 2.7 percent of 2019 GDP in Tajikistan to 5.5 percent in Kyrgyzstan. These are relatively large numbers which add to the estimated value-for-money of policies to tackle RTIs.

A useful by-product of our analysis is a simple algorithm to estimate the Value of Statistical Life and the Value of Statistical Life-Year, starting from data that are widely available, such as the Gross National Income (GNI) and the Health Adjusted Life Expectancy (HALE). This methodology largely draws on Viscusi and Masterman (2017) and is spelled out in (Appendix C). This algorithm will provide a useful tool for countries that do not have estimates of the monetary value of reducing the risk of death, grounded in a solid theoretical basis.

While evidence on the cost burden alone may be helpful in underlining the urgency of the problem, in order to make rational decisions about which RTI policies should be implemented first, policymakers need information not only on the benefits of reducing RTIs, but also on the costs and effects of concrete interventions.

While a detailed identification of the "right" RTI policies to put into place in each of the four countries studied here is beyond the scope of this work, this report will nonetheless provide a foundation for further policy deliberations, along two lines. First, since Chapter 1 focuses on a detailed analysis of the health care costs associated with RTIs, there are some at least tentative implications that may be derived for how to improve health care system response to RTIs. Second, since the key lever for preventing RTIs is located outside the health care system, **Chapter 3 provides a brief synthesis of the existing evidence base regarding the effectiveness and cost-effectiveness of RTI interventions in lower- and middle-income countries (LMICs).**

Currently, the road safety interventions undertaken by the health care system are focused on the post-impact stage and are aimed at preventing death and reducing the severity of injuries once an RTC has occurred. While the focus of this study has been on cost assessment, the results also provide some insights into the need for policy interventions across the "chain of opportunities"—interventions such as emergency rescue, prompt access to emergency and trauma care, and rehabilitation. Further development of these insights would, however, require more and better information on the quality and organization of post-crash care services in Central Asian countries.

There is scope for improving data systems across the transport, health, and police sectors to better enable future quantitative evaluations that can inform system reform. The recording and reporting of injury-related data at various stages of post-crash care are essential in order to identify the priority areas, monitor progress, and evaluate whether the allocation of resources is being appropriately directed, for example by monitoring emergency medical services (EMS) and hospital injury surveillance.

Three main areas for improvement of the responsiveness of health care systems may be worth highlighting:

1. Develop an institutional and regulatory framework for the provision of care at the scene by formal first responders (FRs).

The health care system has an important role to play in coordinating response; in increasing the capacity for injury management, surveillance and data sharing; and in building the evidence base of cost-effective interventions. The effectiveness of emergency rescue operations is critical in reducing deaths and the severity of injuries resulting from road crashes. It is recommended that existing policies be reviewed in light of the new global guidance to allow FR resources (police, fire, and rescue officers) to be focused on those areas of prehospital care that can decrease prehospital deaths and disabling injuries. Emergency rescue requires effective collaboration between *all* emergency and follow-on services, with the aim of ensuring speedy first aid on the scene, and efficient transport to an appropriate health care facility. To achieve this, close cooperation on the scene between fire and rescue workers and/or the police (who may arrive first at the scene) and EMS personnel is needed. Nonmedical emergency services need to be adequately trained in a systematic way so that they can provide immediate first aid and basic life support.

2. Increase access to and the quality of emergency medical services.

Improving the EMS network and coverage should be a key objective in post-crash response in Central Asian countries. Enhancing the regulatory component for the prehospital care governance standards regarding EMS dispatch, triage, ambulance bypass protocols, thresholds for transferring crash casualties, and so on, and their compliance should form the basis of a single nationwide framework. In addition, there is a need to develop standards and implement appropriate clinical protocols that would specify the procedures to be used for the management of crash casualties by EMS on the roads; while in transport; and on arrival in a health care facility, in order to reduce preadmission death rates and/or disability or medical impairment. However, first preliminary work needs to be undertaken to evaluate various characteristics of the emergency medical services that are currently in place.

3. Review the organization of the national trauma care system.

One prerequisite for high-quality trauma care is a strategy for the planning, optimal organization, and provision of a national trauma care system in order to reduce delays in the transfer of crash casualties to the place of definitive treatment. However, data is first required in order to establish the characteristics and the level of performance of the current system.

Regionalization of care in specialized trauma centers should be considered as part of the reorganization. This process should mandatorily define the pathway of care for severely injured casualties; identify the location and capability of each hospital within the trauma system; and outline bypass protocols and thresholds for transferring patients to more specialized units. Within each geographic or administrative region, there should be a network of health care facilities designated to treat trauma patients, ranging from those with life-threatening conditions to those with less complex injuries. Such a "trauma system" would need to integrate prehospital care (that is, the care delivered by EMS at the crash scene); the initial journey to a suitable health care facility; interhospital transfer where required, for patients who need more specialized treatment; definitive hospital treatment; and rehabilitation.

The multidisciplinary trauma team and the minimum threshold of basic clinical capabilities and equipment for each trauma center should be properly addressed by the regulatory framework.

As Chapter 3 highlighted, there is no shortage of general recommendations on key policies that are widely seen as representing an effective response to the reducing of avoidable burden of RTIs. The recommendations for preventing RTIs include:

- ***Reducing risk exposure*** by stabilizing motorization levels, providing alternative modes of travel, and improving land-use planning practices;
- ***Reducing the risk factors directly related to crash causation***, such as speeding, drinking and driving; using unsafe vehicles on unsafe roads (with safety features that are inadequate for the traffic mix); and failing to enforce road safety laws effectively;
- ***Reducing the severity of injuries*** by mandating and enforcing the use of seat belts, child restraints, and helmets, as well as by improving road infrastructure and vehicle design to protect all road users.

These interventions should, however, not be seen as separate from each other. They should be seen as being part of a whole system, the so-called "Safe System" approach (Turner et al. 2021), according to which addressing road safety challenges requires a holistic approach composed of several pillars (Road Safety Management; Safe Roads; Safe Speeds; Safe Vehicles; Safe Road Users; and Post-Crash Care); and recognizing that evidence-based solutions must be drawn from across these pillars in order to produce effective road safety outcomes.

Notwithstanding a broad international consensus that a *set* of effective interventions is necessary in order to produce the desired outcomes, there remains a lack of context-specific evidence from RTI policies in an LMIC context in general, and for these four Central Asian countries specifically. This applies to both evidence of their effectiveness, and– not surprisingly – even more so to their cost-effectiveness. The latter would be particularly useful to inform priority-setting within limited public budgets.

In the scarce LMIC RTI literature that does exist, there are nonetheless some encouraging findings about the "return on investment" of introducing a *set* of RTI interventions, with some polices possibly even paying for themselves through the savings they produce in terms of health care cost avoidance and other potential economic savings. Three interventions—speed enforcement, alcohol enforcement, and safer road infrastructure—are relevant to all road users. Three additional interventions apply only to particular groups: enforcing helmet use (for motorcycle riders); enforcing seat belt use (for occupants of motor vehicles); and setting up graduated licensing schemes for young drivers.

The effectiveness of policy measures will likely vary from country to country. For instance, the type and quality of circulating cars, the quality of road infrastructure, and the regulations that are already in place alter the extent to which speed limits, seat belts, or helmet use will contribute to reducing injuries or fatalities. This observation helps explain why the reduction in RTI mortality that can be achieved by implementing a specific policy is hard to predict *a priori*, and why the literature review in Chapter 3 demonstrates a wide range in the level of effectiveness found for the considered interventions. The heterogenous effects of policy measures imply that the optimal policy mix to be implemented will inevitably vary by country, and requires context-specific analysis.

In order to determine the optimal policy mix, accurate and detailed data on local road traffic intensity and crashes need to be collected systematically. Data should be geographically referenced to identify which portions of the road system, which type of roads (urban, suburban, highways), and which specific junctions are more at risk, and should also identify which times of the day are more at risk, for each road. Automated systems based on sensors and cameras can collect such information. A complementary, and perhaps more convenient way to collect such data may be via drivers' mobile phones, provided that the coverage of smartphones is large enough.

Such data would help the police choose which roads need more monitoring and at what times, given the available resources. The data would also allow policymakers to more precisely estimate the effectiveness of various policy measures and help steer government strategies on road traffic management. A national authority along the lines of the Road Safety Observatory that has been established in the European Union, if endowed with enough statistical and technological expertise, could be in charge of collecting, harmonizing, and analyzing these data. The main goal of such an observatory should be to brief policymakers, thus contributing to designing the most cost-effective policy mix for the specific situation of each country, and adapting it to evolving conditions.

Future research should seek to fill this evidence gap; better contextualize the existing global evidence base; and increase the chances for take-up by national and regional policymakers in lower- and middle-income countries in Central Asia, as well as elsewhere.

APPENDIX A: SELECTED ROAD SAFETY POLICIES IN FOUR CENTRAL ASIAN COUNTRIES

Table A1: Selected Road Safety Policies in Four Central Asian Countries

SAFE SPEEDS

MAXIMUM SPEED LIMITS AND ENFORCEMENT

Kazakhstan

✓	60 km/h	110 km/h	140 km/h	Automated
NATIONAL SPEED LIMIT LAW	URBAN ROADS	RURAL ROADS	MOTORWAYS	SPEED ENFORCEMENT
Difference with Recommended Safe Systems Speeds	+ 30 km/h 6 times lower	+ 40 km/h 6 times lower	+ 50 km/h 5 times lower	Potential Decrease in Fatal Road Crashes from Enforcement of Safe System Speed Limits

Kyrgyzstan

✓	60 km/h	90 km/h	110 km/h	Manual and Automated
NATIONAL SPEED LIMIT LAW	URBAN ROADS	RURAL ROADS	MOTORWAYS	SPEED ENFORCEMENT
Difference with Recommended Safe Systems Speeds	+ 30 km/h 6 times lower	+ 20 km/h 3 times lower	+ 20 km/h 2 times lower	Potential Decrease in Fatal Road Crashes from Enforcement of Safe System Speed Limits

Tajikistan

✓	60 km/h	90 km/h	110 km/h	Manual
NATIONAL SPEED LIMIT LAW	URBAN ROADS	RURAL ROADS	MOTORWAYS	SPEED ENFORCEMENT
Difference with Recommended Safe Systems Speeds	+ 30 km/h 6 times lower	+ 20 km/h 3 times lower	+ 20 km/h 2 times lower	Potential Decrease in Fatal Road Crashes from Enforcement of Safe System Speed Limits

Uzbekistan

✓	70 km/h	100 km/h	Not Known	Manual
NATIONAL SPEED LIMIT LAW	URBAN ROADS	RURAL ROADS	MOTORWAYS	SPEED ENFORCEMENT
Difference with Recommended Safe Systems Speeds	+ 40 km/h 9 times lower	+ 30 km/h 4 times lower	- -	Potential Decrease in Fatal Road Crashes from Enforcement of Safe System Speed Limits

MAJOR SPEED-CALMING MEASURES BEING IMPLEMENTED IN THE FOUR COUNTRIES

Kazakhstan

✗ NARROWING	✓ VERTICAL DEFLECTIONS	✗ HORIZONTAL DEFLECTION	✗ BLOCK OR RESTRICT ACCESS

Kyrgyzstan

✗ NARROWING	✓ VERTICAL DEFLECTIONS	✗ HORIZONTAL DEFLECTION	✗ BLOCK OR RESTRICT ACCESS

Tajikistan

✗ NARROWING	✓ VERTICAL DEFLECTIONS	✗ HORIZONTAL DEFLECTION	✗ BLOCK OR RESTRICT ACCESS

Uzbekistan

✗ NARROWING	✓ VERTICAL DEFLECTIONS	✗ HORIZONTAL DEFLECTION	✗ BLOCK OR RESTRICT ACCESS
Include lane narrowings by extending sidewalks, curb extensions, pedestrian refuges etc.	Include speed bumps, humps, cushions, tables, raised pedestrian crossing, variation in ride surface etc.	Used to make vehicles swerve slightly, include chicanes, pedesrian refuges, chokers etc.	Include median diverters, closing streets to create pedestrian zones, cul-de-sacs etc.

SAFE VEHICLES

VEHICLE REGISTRATION AND IMPORT REGULATIONS

Kazakhstan

TOTAL REGISTERED VEHICLES AS OF 2016	MOTORIZED 2/3 WHEELERS AS OF 2016
4,383,120	0.2%

COUNTRY COMPLIANCE TO THE UN VEHICLE SAFETY REGULATIONS	
FRONTAL AND SIDE IMPACT (Reg. 94, 95)	✗
MOTORCYCLE ANTI-LOCK BRAKING SYSTEM (Reg. 78)	✗
PEDESTRIAN PROTECTION (Reg. 127)	✗
ELECTRONIC STABILITY CONTROL (Reg. 140)	✗
SEAT BELTS AND ANCHORAGES (Reg. 16, 14)	✗

REGULATION OF IMPORT OF USED VEHICLES	IMPORT AGE LIMIT	TAXATION BASED LIMITS	IMPORT INSPECTIONS	PERIODIC INSPECTION
✓ Regulated	✓ 10 Yrs.	✗ No	✓ Yes	✗ No

Kyrgyzstan

TOTAL REGISTERED VEHICLES AS OF 2016	MOTORIZED 2/3 WHEELERS AS OF 2016
958,187	2.3%

COUNTRY COMPLIANCE TO THE UN VEHICLE SAFETY REGULATIONS	
FRONTAL AND SIDE IMPACT (Reg. 94, 95)	✗
MOTORCYCLE ANTI-LOCK BRAKING SYSTEM (Reg. 78)	✗
PEDESTRIAN PROTECTION (Reg. 127)	✗
ELECTRONIC STABILITY CONTROL (Reg. 140)	✗
SEAT BELTS AND ANCHORAGES (Reg. 16, 14)	✗

REGULATION OF IMPORT OF USED VEHICLES	IMPORT AGE LIMIT	TAXATION BASED LIMITS	IMPORT INSPECTIONS	PERIODIC INSPECTION
✓ Regulated	✓ 10 Yrs.	✗ No	✓ Yes	✗ No

Tajikistan

TOTAL REGISTERED VEHICLES AS OF 2016	MOTORIZED 2/3 WHEELERS AS OF 2016
439,972	1.0%

COUNTRY COMPLIANCE TO THE UN VEHICLE SAFETY REGULATIONS	
FRONTAL AND SIDE IMPACT (Reg. 94, 95)	✗
MOTORCYCLE ANTI-LOCK BRAKING SYSTEM (Reg. 78)	✗
PEDESTRIAN PROTECTION (Reg. 127)	✗
ELECTRONIC STABILITY CONTROL (Reg. 140)	✗
SEAT BELTS AND ANCHORAGES (Reg. 16, 14)	✗

REGULATION OF IMPORT OF USED VEHICLES	IMPORT AGE LIMIT	TAXATION BASED LIMITS	IMPORT INSPECTIONS	PERIODIC INSPECTION
✗ No Restrictions	✗ No	✗ No	✓ Yes	✗ No

Uzbekistan

TOTAL REGISTERED VEHICLES AS OF 2016	MOTORIZED 2/3 WHEELERS AS OF 2016
Not Known	Not Known

COUNTRY COMPLIANCE TO THE UN VEHICLE SAFETY REGULATIONS	
FRONTAL AND SIDE IMPACT (Reg. 94, 95)	✗
MOTORCYCLE ANTI-LOCK BRAKING SYSTEM (Reg. 78)	✗
PEDESTRIAN PROTECTION (Reg. 127)	✗
ELECTRONIC STABILITY CONTROL (Reg. 140)	✗
SEAT BELTS AND ANCHORAGES (Reg. 16, 14)	✗

REGULATION OF IMPORT OF USED VEHICLES	IMPORT AGE LIMIT	TAXATION BASED LIMITS	IMPORT INSPECTIONS	PERIODIC INSPECTION
✗ No Restrictions	✗ No	✗ No	✓ Yes	✗ No

SAFE ROAD USERS

NATIONAL SEAT BELT, DRINK DRIVING, AND HELMET LAWS

Kazakhstan

NATIONAL SEATBELT LAW	DRIVER	FRONT	BACK	MOTORCYCLE HELMET LAW	HELMET STANDARDS	MOTORCYCLE OCCUPANT AGE RESTRICTION	LEGAL MINIMUM DRIVING AGE
✓	✓	✓	✓	✓	✗	✓ Prohibited under 12 yrs	✓ 18 yrs.

NATIONAL DRINK DRIVING LAW	IS LAW BAC BASED?	BLOOD ALCOHOL CONCENTRATION (BAC) LIMITS (g/dl): GENERAL POPULATION	YOUNG DRIVERS	PROFESSIONAL DRIVERS	RANDOM DRINK DRIVING TESTS	% OF ROAD CRASH FATALITIES INVOLVING ALCOHOL
✓	✓	<0.05	<0.05	<0.05	✗	Approx. 0.3%

Kyrgyzstan

NATIONAL SEATBELT LAW	DRIVER	FRONT	BACK	MOTORCYCLE HELMET LAW	HELMET STANDARDS	MOTORCYCLE OCCUPANT AGE RESTRICTION	LEGAL MINIMUM DRIVING AGE
✓	✗	✗	✗	✓	✗	✓ Prohibited under 12 yrs	✓ 18 yrs.

NATIONAL DRINK DRIVING LAW	IS LAW BAC BASED?	BLOOD ALCOHOL CONCENTRATION (BAC) LIMITS (g/dl): GENERAL POPULATION	YOUNG DRIVERS	PROFESSIONAL DRIVERS	RANDOM DRINK DRIVING TESTS	% OF ROAD CRASH FATALITIES INVOLVING ALCOHOL
✓	✗	✗	✗	✗	✓	✗ Not Known

SAFE ROAD USERS (CONT)

NATIONAL SEAT BELT, DRINK DRIVING, AND HELMET LAWS

Tajikistan

NATIONAL SEATBELT LAW	DRIVER	FRONT	BACK	MOTORCYCLE HELMET LAW	HELMET STANDARDS	MOTORCYCLE OCCUPANT AGE RESTRICTION	LEGAL MINIMUM DRIVING AGE
✓	✓	✓	✗	✓	✗	✓ Prohibited under 12 yrs	✓ 18 yrs.

NATIONAL DRINK DRIVING LAW	IS LAW BAC BASED?	GENERAL POPULATION	YOUNG DRIVERS	PROFESSIONAL DRIVERS	RANDOM DRINK DRIVING TESTS	% OF ROAD CRASH FATALITIES INVOLVING ALCOHOL
		BLOOD ALCOHOL CONCENTRATION (BAC) LIMITS (g/dl)				
✓	✗	✗	✗	✗	✓	Approx. 4.2%

Uzbekistan

NATIONAL SEATBELT LAW	DRIVER	FRONT	BACK	MOTORCYCLE HELMET LAW	HELMET STANDARDS	MOTORCYCLE OCCUPANT AGE RESTRICTION	LEGAL MINIMUM DRIVING AGE
✓	✓	✗	✗	✓	✗	✓ Prohibited under 12 yrs	✓ 18 yrs.

NATIONAL DRINK DRIVING LAW	IS LAW BAC BASED?	GENERAL POPULATION	YOUNG DRIVERS	PROFESSIONAL DRIVERS	RANDOM DRINK DRIVING TESTS	% OF ROAD CRASH FATALITIES INVOLVING ALCOHOL
		BLOOD ALCOHOL CONCENTRATION (BAC) LIMITS (g/dl)				
✓	✗	✗	✗	✗	✓	Approx. 3.6%

Kazakhstan

NATIONAL EMERGENCY CARE ACCESS NUMBER	TRAUMA REGISTRY SYSTEM	COUNTRY HEALTH COVERAGE INDEX - SDG Target 3.8; Target - 100	EXPENDITURE ON HEALTHCARE AS % OF GDP
National, Multiple Numbers	National	71	4%

Kyrgyzstan

NATIONAL EMERGENCY CARE ACCESS NUMBER	TRAUMA REGISTRY SYSTEM	COUNTRY HEALTH COVERAGE INDEX - SDG Target 3.8; Target - 100	EXPENDITURE ON HEALTHCARE AS % OF GDP
National, Multiple Numbers	None	66	7%

Tajikistan

NATIONAL EMERGENCY CARE ACCESS NUMBER	TRAUMA REGISTRY SYSTEM	COUNTRY HEALTH COVERAGE INDEX - SDG Target 3.8; Target - 100	EXPENDITURE ON HEALTHCARE AS % OF GDP
National, Multiple Numbers	National	65	7%

Uzbekistan

NATIONAL EMERGENCY CARE ACCESS NUMBER	TRAUMA REGISTRY SYSTEM	COUNTRY HEALTH COVERAGE INDEX - SDG Target 3.8; Target - 100	EXPENDITURE ON HEALTHCARE AS % OF GDP
National, Multiple Numbers	Not Known	72	6%

Source: World Bank 2019

APPENDIX B:
ADDITIONAL DETAILS REGARDING MATHEMATICAL FORMULATION OF THE MODEL AND DATA SOURCES

This appendix provides additional details related to this study, including the mathematical formulation of the model, and detailed data sources.

The RTI-related health care costs were estimated based on only the main cost categories that should be taken into account in all cases (prehospital emergency care, outpatient care, hospital care, and long-term care), since minor costs (for example, medical appliances) are known to be unsubstantial in size compared to the main costs. The defined health care cost categories are to a large extent in line with those reported in the related literature (Kasnatscheew et al. 2016; Wijnen et al. 2017).

RTI-Related Health Care Consumption

Tables B1 – B15 show the distribution of injured body regions, and of AIS injury severity for various collision configurations, considering the following potential contributory factors: crash opponents, vehicle body type, vehicle model year, occupant position, seat belt and helmet use, and age.

Table B1. AIS Injury Distribution for Pedestrians (0-17 years old) in Collision with Cars & Other Light Vehicles, Model Year Pre-2006

INJURIES TO HEAD	INJURIES TO NECK	INJURIES TO THORAX	INJURIES TO ABDOMEN	INJURIES TO PELVIS	INJURIES TO UPPEXT	INJURIES TO LOWEXT	INJURIES TO UNSPECIFIED BODY REGION
0.434	0.013	0.075	0.051	0.034	0.088	0.299	0.006

AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 6
0.651	0.185	0.107	0.029	0.023	0.005

* Based on estimates from IHRA Pedestrian Traffic Accident Study, 2003.

Table B2. AIS Injury Distribution for Pedestrians (18-59 years old) in Collision with Cars & Other Light Vehicles, Model Year Pre-2006

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.250	0.104	0.646	Injuries to Head	0.271
Injuries to Neck	0.541	0.245	0.214	Injuries to Neck	0.026
Injuries to Thorax	0.146	0.096	0.758	Injuries to Thorax	0.061
Injuries to Abdomen	0.381	0.428	0.191	Injuries to Abdomen	0.050
Injuries to Pelvis	0.240	0.509	0.251	Injuries to Pelvis	0.050
Injuries to UppExt	0.330	0.649	0.020	Injuries to UppExt	0.153
Injuries to LowExt	0.536	0.221	0.243	Injuries to LowExt	0.369
Injuries to Unspecified Body Region	0.346	0.322	0.332	Injuries to Unspecified Body Region	0.020

* Based on estimates from Wisch et al., 2017

Table B3. AIS Injury Distribution for Pedestrians (60+ years old) in Collision with Cars & Other Light Vehicles, Model Year Pre-2006

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.323	0.073	0.604	Injuries to Head	0.271
Injuries to Neck	0.164	0.055	0.781	Injuries to Neck	0.026
Injuries to Thorax	0.202	0.185	0.613	Injuries to Thorax	0.061
Injuries to Abdomen	0.274	0.528	0.198	Injuries to Abdomen	0.050
Injuries to Pelvis	0.198	0.498	0.304	Injuries to Pelvis	0.050
Injuries to UppExt	0.426	0.554	0.020	Injuries to UppExt	0.153
Injuries to LowExt	0.398	0.370	0.232	Injuries to LowExt	0.369
Injuries to Unspecified Body Region	0.284	0.323	0.393	Injuries to Unspecified Body Region	0.020

* Based on estimates from Wisch et al. 2017

Table B4. AIS Injury Distribution for Pedestrians (All Ages) in Collision with Heavy Trucks and Buses

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.660	0.070	0.270	Injuries to Head	0.433
Injuries to Neck	0.790	0.180	0.030	Injuries to Neck	0.088
Injuries to Thorax	0.590	0.100	0.310	Injuries to Thorax	0.104
Injuries to Abdomen	0.760	0.120	0.120	Injuries to Abdomen	0.075
Injuries to UppExt	0.590	0.330	0.080	Injuries to UppExt	0.150
Injuries to LowExt	0.419	0.291	0.290	Injuries to LowExt	0.150
Injuries to Unspecified Body Region	0.635	0.182	0.183	Injuries to Unspecified Body Region	0.000

* Based on estimates from Malczyk et al. 2019

Table B5. AIS Injury Distribution for Cyclists (0-17 years old, Non-Helmeted or Unknown) in Collision with Cars & Other Light Vehicles, All Model Years

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.593	0.204	0.204	Injuries to Head	0.244
Injuries to Neck	0.800	0.200	0.000	Injuries to Neck	0.022
Injuries to Thorax	0.333	0.333	0.333	Injuries to Thorax	0.087
Injuries to Abdomen	0.500	0.500	0.000	Injuries to Abdomen	0.078
Injuries to UppExt	0.500	0.500	0.000	Injuries to UppExt	0.307
Injuries to LowExt	0.500	0.500	0.000	Injuries to LowExt	0.260
Injuries to Unspecified Body Region	0.538	0.372	0.090	Injuries to Unspecified Body Region	0.002

* Based on estimates from Malczyk et al. 2015

Table B6. AIS Injury Distribution for Cyclists (18-59 years old, Non-Helmeted or Unknown) in Collision with Cars & Other Light Vehicles, All Model Years

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.755	0.161	0.084	Injuries to Head	0.244
Injuries to N eck	0.857	0.100	0.043	Injuries to Neck	0.022
Injuries to Thorax	0.636	0.243	0.121	Injuries to Thorax	0.087
Injuries to Abdomen	0.767	0.186	0.047	Injuries to Abdomen	0.078
Injuries to UppExt	0.662	0.336	0.002	Injuries to UppExt	0.307
Injuries to LowExt	0.783	0.177	0.040	Injuries to LowExt	0.260
Injuries to Unspecified Body Region	0.743	0.201	0.056	Injuries to Unspecified Body Region	0.002

* Based on estimates from Wisch et al. 2017

Table B7. AIS Injury Distribution for Cyclists (60+ years old, Non-Helmeted or Unknown) in Collision with Cars & Other Light Vehicles, All Model Years

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.626	0.179	0.195	Injuries to Head	0.244
Injuries to Neck	0.617	0.170	0.213	Injuries to Neck	0.022
Injuries to Thorax	0.437	0.283	0.280	Injuries to Thorax	0.087
Injuries to Abdomen	0.571	0.372	0.058	Injuries to Abdomen	0.078
Injuries to UppExt	0.607	0.381	0.012	Injuries to UppExt	0.307
Injuries to LowExt	0.620	0.244	0.136	Injuries to LowExt	0.260
Injuries to Unspecified Body Region	0.580	0.272	0.148	Injuries to Unspecified Body Region	0.002

* Based on estimates from Wisch et al. 2017

Table B8. AIS Injury Distribution for Cyclists (All ages, Non-Helmeted or Unknown) in Collision with Heavy Trucks and Buses

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.750	0.030	0.210	Injuries to Head	0.244
Injuries to Neck	0.758	0.157	0.085	Injuries to Neck	0.022
Injuries to Thorax	0.630	0.070	0.300	Injuries to Thorax	0.087
Injuries to Abdomen	0.710	0.165	0.125	Injuries to Abdomen	0.078
Injuries to UppExt	0.640	0.290	0.070	Injuries to UppExt	0.307
Injuries to LowExt	0.350	0.250	0.400	Injuries to LowExt	0.260
Injuries to Unspecified Body Region	0.641	0.161	0.198	Injuries to Unspecified Body Region	0.002

* Based on estimates from Malczyk et al. 2019

Table B9. AIS Injury Distribution for Motorcyclists (18+ years old, Non-Helmeted or Unknown), All Collisions

	AIS 1	AIS 2	AIS 3+		
Injuries to Head	0.399	0.443	0.159	Injuries to Head	0.198
Injuries to Neck	0.812	0.088	0.100	Injuries to Neck	0.035
Injuries to Thorax	0.622	0.236	0.143	Injuries to Thorax	0.139
Injuries to Abdomen	0.712	0.194	0.095	Injuries to Abdomen	0.067
Injuries to UppExt	0.788	0.187	0.026	Injuries to UppExt	0.234
Injuries to LowExt	0.746	0.154	0.100	Injuries to LowExt	0.298
Injuries to Unspecified Body Region	0.680	0.217	0.103	Injuries to Unspecified Body Region	0.029

* Based on estimates from Otte et al. 2013

Table B10. AIS Injury Distribution for Cars & Other Light Vehicles Drivers (18-59 years old) in Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

	AIS 1-3	AIS 4-6
Injuries to Head	0.149	0.588
Injuries to Face	0.190	0.000
Injuries to Neck (throat)	0.011	0.004
Injuries to Thorax	0.070	0.275
Injuries to Abdomen	0.035	0.049
Injuries to Neck (spine)	0.108	0.049
Injuries to UppExt	0.252	0.000
Injuries to LowExt	0.171	0.007
Injuries to Unspecified Body Region	0.013	0.028
Proportion	0.982	0.017

* Based on estimates from Liu et al. 2007

Table B11. AIS Injury Distribution for Cars & Other Light Vehicles Drivers (60+ years old) in Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

	AIS 1-3	AIS 4-6
Injuries to Head	0.163	0.255
Injuries to Face	0.110	0.000
Injuries to Neck (throat)	0.007	0.007
Injuries to Thorax	0.099	0.556
Injuries to Abdomen	0.029	0.009
Injuries to Neck (spine)	0.058	0.053
Injuries to UppExt	0.335	0.000
Injuries to LowExt	0.190	0.038
Injuries to Unspecified Body Region	0.010	0.082
Proportion	0.975	0.025

* Based on estimates from Liu et al. 2007

Table B12. AIS Injury Distribution for Cars & Other Light Vehicles Drivers (18-59 years old) in Non-Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

	AIS 1-3	AIS 4-6
Injuries to Head	0.099	0.531
Injuries to Face	0.158	0.001
Injuries to Neck (throat)	0.013	0.001
Injuries to Thorax	0.091	0.298
Injuries to Abdomen	0.035	0.088
Injuries to Neck (spine)	0.182	0.055
Injuries to UppExt	0.203	0.000
Injuries to LowExt	0.219	0.002
Injuries to Unspecified Body Region	0.000	0.024
Proportion	0.992	0.008

* Based on estimates from Liu et al. 2007

Table B13. AIS Injury Distribution for Cars & Other Light Vehicles Drivers (60+ years old) in Non-Rollover Collisions (Belted and Non-Belted, Model Year Pre-2006)

	AIS 1-3	AIS 4-6
Injuries to Head	0.111	0.448
Injuries to Face	0.152	0.000
Injuries to Neck (throat)	0.008	0.000
Injuries to Thorax	0.133	0.384
Injuries to Abdomen	0.025	0.092
Injuries to Neck (spine)	0.119	0.068
Injuries to UppExt	0.233	0.000
Injuries to LowExt	0.215	0.004
Injuries to Unspecified Body Region	0.005	0.005
Proportion	0.983	0.017

* Based on estimates from Liu et al. 2007

Table B14. AIS Injury Distribution for Cars & Other Light Vehicles (Occupants 0-17 years old) in All Collisions (Belted and Non-Belted, Model Year Pre-2006)

	AIS 1-3	AIS 4-6
Injuries to Head	0.402	0.402
Injuries to Face	0.063	0.063
Injuries to Neck (throat)	0.156	0.156
Injuries to Thorax	0.128	0.128
Injuries to Abdomen	0.019	0.019
Injuries to Neck (spine)	0.094	0.094
Injuries to UppExt	0.138	0.138
Injuries to LowExt	0.360	0.640
Proportion	0.983	0.017

* Based on estimates from Hanna 2010

Table B15. AIS Injury Distribution for Cars & Other Light Vehicles (Occupants 18+ years old) in All Collisions (Belted and Non-Belted, Model Year Pre-2006)

	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 6		
Injuries to Head	0.597	0.212	0.076	0.065	0.045	0.006	Injuries to Head	0.162
Injuries to Face	0.842	0.136	0.019	0.003	0.000	0.000	Injuries to Face	0.126
Injuries to Neck	0.998	0.002	0.000	0.000	0.000	0.000	Injuries to Neck	0.065
Injuries to Thorax	0.579	0.111	0.229	0.074	0.006	0.001	Injuries to Thorax	0.150
Injuries to Abdomen	0.491	0.229	0.193	0.087	0.000	0.000	Injuries to Abdomen	0.035
Injuries to Dorso Lumbar Column	0.628	0.300	0.057	0.002	0.013	0.000	Injuries to Dorso Lumbar Column	0.087
Injuries to UppExt	0.722	0.222	0.056	0.000	0.000	0.000	Injuries to UppExt	0.164
Injuries to LowExt	0.733	0.165	0.102	0.000	0.000	0.000	Injuries to LowExt	0.165
Injuries to Pelvis	0.542	0.308	0.147	0.003	0.000	0.000	Injuries to Pelvis	0.046
Injuries to Unspecified Body Region	0.681	0.187	0.098	0.026	0.007	0.001	Injuries to Unspecified Body Region	0.000

* Based on estimates from Page et al. 2012

It is important to acknowledge that polytrauma was defined as two or more severe injuries (AIS 3+) in at least two regions of the body. (This term lacks a universally accepted and validated definition.) At the same time there is compelling evidence that the recently recommended AIS > 2 in at least two body regions (2 × AIS > 2) has higher accuracy and precision in defining polytrauma than ISS > 15 and ISS > 17 (Butcher and Balogh 2012). These simple, retrospective, and reproducible criteria warrant validation on a larger scale. For each road user category, the polytrauma casualties were calculated from the AIS 3+ injuries group by using the rates derived from the study on serious RTIs in the European Union (Aarts et al. 2016). This study was selected to form the base estimates because in-depth crash databases, trauma registers, hospital information systems, and linked police-hospital databases, including crash-contributing factors and scenarios, were used to estimate injury outcomes. Furthermore, it appeared to be methodologically rigorous and presented data in a transparent format.

Table B16. Polytrauma Rate in Road Users' Categories

Pedestrians	0.102
Cyclists	0.083
Motorized 2- or 3-wheeler users	0.125
Motorized 4-wheeler users	0.146

A major characteristic of this cost model is its use of transition ratios: the probability that an RTC casualty will use a certain form of health care—for example, the probability of transfer by ambulance from the crash location to the hospital; the probability of hospitalization; and/or the probability of admission for rehabilitative care. However, not all of these data are available in Central Asian countries. The four Central Asian countries studied for this report presented variation in the RTC casualty's pathway, mainly related to health care system factors that showed that certain types of health care, such as prehospital emergency and rehabilitative care, were less commonly delivered than acute inpatient care. Some countries (for example, Kazakhstan) provided data on the transition ratio of hospitalization from the overall injury admissions at emergency departments (EDs). The assumption that RTC-injured casualties would have the same transition ratio between types of care could produce artificial variation in the volumes of care consumed and their subsequent costs. Other countries (for example, Tajikistan) reported a 1.0 transition ratio of hospitalization for all severely injured casualties, and a transition ratio of 0.0 for all slightly injured casualties. The basic assumption that the extra road traffic crash (RTC) casualties were not directly admitted to the hospital having received no treatment in EMS or ED and that the slightly injured casualties were not hospitalized are not always congruent with clinical practice and RTC casualty pathways in Central Asian countries. At the same time, it is reasonable to assume that the likelihood of an injured person to be admitted to hospital given a particular type and severity of injury, will be constant over time.

In addition to the data on transition probabilities that was provided by the countries we studied, we conducted a review of national and international literature to form the base estimates. It is important to acknowledge that input values for different road users and health care types were not estimated based on standard definitions, and therefore could introduce bias. Furthermore, the bias could be more serious for some base estimates than for others. Unfortunately, this is an unresolvable limitation at this stage due to the heterogeneity in definitions and measurements across studies and reports. In cases where input values were not statistically significant, or where they constituted rough calculations, the confidence limits of base estimates were not calculated. However, these are the best achievable estimates given the available data, and should be regarded as such. Table B17 presents the other base estimates for health care consumption and data sources in the cost model.

Table B17. Other Base Estimates for Health Care Consumption and Data Sources

MODEL PARAMETER	KAZ	KGZ	TJK	UZB
Death on crash scene	0.670**	0.700***	0.810**	0.709**
Death at arrival at hospital	0.010*	0.000**	0.003*	0.000*
Death at the hospital	0.320**	0.300***	0.187***	0.291***
RTC injured casualties' ambulance attendance	0.650**	0.200**	0.010**	0.200***
Hospital referral by EMS	0.520*	0.980*	0.610*	0.370***
Outpatient referral by EMS	0.480***	0,020***	0.390***	0.630***
Hospital referral by ED	0.140***	NA	NA	NA
Outpatient referral by ED	0.250***	NA	NA	NA
Hospital referral by specialized outpatient	0.025***	0.025***	0.025***	0.025***
Hospital self-referral	0.800***	0.700***	0.800***	0.700***
ED self-referral	0.150***	NA	NA	NA
Outpatient self-referral	0.005***	0.300***	0.200***	0.300***
Interhospital transfer	0.094**	0.094**	0.094**	0.094**
No. of OSAR treatment courses (episodes of care)	2.0***	2.0***	2.0***	2.0***
No. of HSAR treatments courses (episodes of care)	3.0***	3.0***	3.0*	3.0***

NA – not applicable
* Estimated based on health care system-reported data
** Estimated based on literature-reported data
*** Calculated/defined based on conservative estimates or normative judgments/policy targets within the health care system.
OSAR= Outpatient Sub-Acute and Rehabilitative Care
HSAR= Hospital Sub-Acute and Rehabilitative Care

Cost valuation included ambulatory visits related to episodes of acute care, but was limited to the period of 90 days from the index visit[27] to outpatient settings or hospitalization from the beginning of the episode of acute care. The methodology assumed that a large majority of episodes of acute care during this time period should be resolved or reevaluated as episodes of long-term care.

The following formula was used to calculate hospitalized RTC casualties when there was confounding data presented by the country for the relationship between the hospitalized, the severely injured, and the slightly injured.

$$\text{Hospitalized} = \text{Severely Injured} + 0{,}253\ \text{Slightly Injured}$$ [28]

The methodology approached RTC-related hospital care as episodes of acute care with the need for treatment and medication at the critical or acute level (including ICU, surgical procedures, etc.), and the need for daily intensive diagnostic or invasive testing.

Valuation of the long-term care attributable to the health care costs of a road traffic injury faces several uncertainties due to (1) high variations in the duration of long-term care; (2) a broad spectrum of subacute and nonacute care to be consumed; (3) unclear cost trajectory patterns for the duration of long-term care; and (4) insufficiently organized service capacity or national coordination. Consequently, this study approached RTI-related long-term care as episodes of general subacute and rehabilitative care of medical impairments for a 15-month period following the three months after the road traffic accident, since approximately 75-90 percent of health care costs are estimated to occur in the first 18 months after a road traffic accident (Lawrence et al. 2014). The transition probabilities were determined using the eligibility criteria for general subacute and rehabilitative care, and a medical impairments profile.

Long-term-care cost estimations were subject to several limitations that underestimate the lifetime health care consumption. First, it covered only subacute care (general and rehabilitative), and excluded nonacute and other types of subacute care such as psychological care, formal home care, and nursing home care. Second, the cost estimates were limited to functional consequences and did not include psychological consequences as part of the RTI-related health cost. Third, the cost valuation did not include disability; it only included medical impairment.[29]

The predicted number of medically impaired RTC casualties was calculated by accumulating the risk for all RTC casualties to sustain at least a 1 percent permanent medical impairment (PMI). The risk of impairment for different body regions and AIS levels is based on PMI scales – 1%+, 5%+ and 10%+ (Malm et al. 2008). The risks for the lower AIS levels, 1 and 2, are much lower than the risks for higher AIS levels, but because AIS1 and AIS2 injuries are so frequent, the majority of impairments have been sustained from the lower-level AIS injuries. Further, the predicted number of casualties that consumed hospital sub-acute and rehabilitative care (HSAR) care was calculated by applying the PMI 5%+ scale. Outpatient sub-acute and rehabilitative care (OSAR) was estimative, consumed by the difference between RTC casualties PMI 1%+ and PMI 5%+.

27 Index visit refers to the first visit (regardless of disposition) for a unique patient or any successive visits in which the patient had no prior visit or hospitalization.

28 French National Institute for Transport and Safety Research (INRETS) formula, based on a crash injury register carried out in the Rhone region of France.

29 Disability is defined as an important limitation to carrying out everyday activities that have lasted, or are expected to last, for more than one year, and whose origin is impairment. Impairment is understood to be any loss or anomaly of an organ, or of the function of that organ, including psychological impairments.

Table B18. Risk of Permanent Medical Impairment on 1%+ and 5%+ levels

	PMI ON 1%+ LEVEL					PMI ON 5%+ LEVEL				
	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5	AIS 1	AIS 2	AIS 3	AIS 4	AIS 5
Head	0.080	0.150	0.500	0.800	1.000	0.050	0.120	0.450	0.800	1.000
Cervical spine	0.167	0.610	0.800	1.000	1.000	0.097	0.400	0.550	1.000	1.000
Face	0.058	0.280	0.800	0.800	NA	0.024	0.100	0.600	0.600	NA
Upper extremity	0.174	0.350	0.850	1.000	NA	0.042	0.100	0.650	1.000	NA
Lower extremity	0.176	0.500	0.600	0.600	1.000	0.016	0.200	0.350	0.600	1.000
Thorax	0.026	0.040	0.040	0.300	0.200	0.000	0.005	0.007	0.150	0.150
Thoracic spine	0.049	0.450	0.900	1.000	1.000	0.009	0.200	0.550	1.000	1.000
Abdomen	0.000	0.024	0.100	0.200	0.200	0.000	0.000	0.045	0.100	0.100
Lumbar spine	0.057	0.550	0.700	1.000	1.000	0.016	0.250	0.450	1.000	1.000
External (skin)	0.017	0.200	0.500	0.500	1.000	0.002	0.070	0.500	0.500	1.000

Road Traffic Crashes

Data preparation had been undertaken before any modeling was made, in order to generate internationally comparable data: for example, making new variables; grouping items within a variable; making groups within a variable dividing/merging *age* in three different age groups; and merging *transport mode* into five groups (pedestrians; motorized four-wheeler occupants; motorized two-three-wheeler users and cyclists; other or unspecified groups).

Table B19. Country-Reported and Estimated Number of Road Traffic Deaths

	REPORTED ROAD TRAFFIC DEATHS				ESTIMATED ROAD TRAFFIC DEATHS			
	KAZ	KGZ	TJK	UZB	KAZ	KGZ	TJK	UZB
Pedestrians	863	364	172	1191	976	364	636	1385
Cyclists	18	12	10	206	54	12	36	239
Motorized 2- or 3-wheeler users	188	20	0	156	136	20	9	181
Motorized 4-wheeler users	1411	259	245	1556	1888	259	896	1812
Other or unspecified users	145	283	0	0	104	283	0	0
Total	2625	938	427	3109	3158	938	1577	3617

Table B20. Country-Reported and Estimated Number of RTC-Injured Casualties

	REPORTED RTC INJURED CASUALTIES				CORRECTION FACTOR	ESTIMATED RTC INJURED CASUALTIES			
	KAZ	KGZ	TJK	UZB		KAZ	KGZ	TJK	UZB
Pedestrians	7984	2352	535	4580	1.88	15010	4422	1006	8610
Cyclists	306	105	50	539	5.38	1646	565	269	3169
Motorized 2- or 3-wheeler users	169	187	0	1163	2.38	402	445	19	2768
Motorized 4-wheeler users	14575	2454	832	6333	1.63	23757	4000	1343	10323
Other or unspecified users	120	3794	2	0	2.25	270	8537	5	0
Total	23154	8892	1419	12655		41086	17968	2641	24870

Table B21. Other Base Estimates for Road Traffic Crashes and Data Sources

MODEL PARAMETER	KAZ	KGZ	TJK	UZB
Share of registered vehicles of MY pre-2006	0.65*	0.96**	0.96**	0.65**
Share of registered vehicle of MY post-2006	0.35*	0.04**	0.04**	0.35**
Seat belt use rate	0.81*	0.66**	0.23**	0.65***
Motorcycle helmet use rate	0.44*	0.10**	0.10**	0.10**
Cyclist helmet use rate	0.06**	0.005***	0.005***	0.005***
4-Wheeler MV Rollover collisions	0.104*	0.107*	0.131*	0.059*
4-Wheeler MV Non-Rollover collisions	0.896*	0.893*	0.869*	0.941*
MV Drivers (as share of Motorized 4-wheeler users)	0.52*	0.50***	0.34*	0.50***

* Estimated based on country-reported data
** Estimated based on literature-reported data
*** Calculated/defined based on conservative estimates

RTI Cost Valuation Techniques

Table B22. Cost Valuation Techniques by Country

	KAZ	KGZ	TJK	UZB
EMS	Restitution Costs	Top-down micro-costing	Restitution Costs	Top-down micro-costing
ED care	Restitution Costs	NA	NA	NA
Outpatient care	Restitution Costs	Restitution Costs	Restitution Costs	Restitution Costs
Hospital care	Restitution Costs	Restitution Costs	Restitution Costs	Restitution Costs
Long-term care	Restitution Costs	Restitution Costs	Restitution Costs	Restitution Costs

Health care costs were estimated by computing the costs for each type of care consumed. In case of fatality, the total health care costs included all cost categories that the patient was included in until his or her death; while in the case of severe and slight injuries the costs were estimated per type of care by place of recovery.

The methodology established the ambulance journey for valuation of the ambulance unit cost regardless of whether this resulted in (1) provision of medical care to the injured person at the crash site; (2) reference for further treatment without being conveyed from the crash site; or (3) transportation of the injured person to a health care facility. Also, the cost of the ambulance journey was included in additional resources and activities associated with road crashes; this could make the cost of service higher through the dispatching of additional higher-skilled personnel to the crash site (paramedic, physician, etc.); administration of medical procedures and medicines above the standard protocol; extra time spent at the crash site (i.e. every 15 minutes thereafter 45 minutes in a metropolitan catchment area).

Table B23. Costs of Emergency Medical Services (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
BLS Ambulance Std-distance	Journey	3031.75	27.19	502.33	30.01	11.70	5.76	83798.00	71.02
BLS Ambulance Long-distance	Journey	-		653.03	39.01	1218.67	600.33	-	-
ALS Ambulance Std-distance	Journey	3336.05	30.10	602.79	36.01	16.10	7.93	-	-
ALS Ambulance Long-distance	Journey	-		783.63	46.81	1520.00	748.77	-	-
Air Ambulance	Journey	820100	7400.29	NA	NA	NA	NA	NA	NA

Source: Authors' calculations, based on national regulations on medical tariffs, and country-reported data.

Table B24. Costs of Emergency Department Services (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
CHILDREN									
Injuries to Head	Visit	1647.24	14.86	-	-	-	-	-	-
Injuries to Neck	Visit	1647.24	14.86	-	-	-	-	-	-
Injuries to Thorax	Visit	1863.97	16.82	-	-	-	-	-	-
Injuries to Abdomen	Visit	1863.97	16.82	-	-	-	-	-	-
Injurie to UppExt	Visit	1994.02	17.99	-	-	-	-	-	-
Injuries to LowExt	Visit	1744.77	15.74	-	-	-	-	-	-
Injuries to Multiple Regions	Visit	3760.46	33.93	-	-	-	-	-	-
Injuries to Unspecified Region	Visit	1148.73	10.37	-	-	-	-	-	-
ADULTS									
Injuries to Head	Visit	2026.54	18.29	-	-	-	-	-	-
Injuries to Neck	Visit	2026.54	18.29	-	-	-	-	-	-
Injuries to Thorax	Visit	1690.58	15.26	-	-	-	-	-	-
Injuries to Abdomen	Visit	1690.58	15.26	-	-	-	-	-	-
Injurie to UppExt	Visit	2059.04	18.58	-	-	-	-	-	-
Injuries to LowExt	Visit	1896.49	17.11	-	-	-	-	-	-
Injuries to Multiple Regions	Visit	3760.46	33.93	-	-	-	-	-	-
Injuries to Unspecified Region	Visit	1408.82	12.71	-	-	-	-	-	-

Source: Authors' calculations, based on national regulations on medical tariffs, and country-reported data.

For inpatient care, the cost assigned to a patient group (injury by type and severity) was estimated as an average value of the prices corresponding to specific ICD-9 codes (or ICD-10 equivalent) according to the Barell Injury Diagnosis Matrix. Further, the weighted mean cost was used for calculations within this cost category (for example, the cost of a hospital stay ending in death). For outpatient care, the unit cost was established as course of treatment (episode of care) in ambulatory settings, considering the need for homogeneity in care consumption and uniformity in cost-item coverage (visits, procedures, medicines, medical tests, etc.). In Kazakhstan, the tariffs for health conditions that are eligible for management in ambulatory settings (that is, an inpatient substitution setting), according to the approved methodology on cost valuation, were calculated by halving the weighting coefficients for corresponding diagnosis-related groups (DRGs) and multiplying them by the established base rate. This approach was extrapolated for Kyrgyzstan. In the case of Uzbekistan and Tajikistan, taking into consideration that the tariff methodology did not apply a base rate or relative cost weights to the groupings (which would allow the calculation of budget-neutral tariffs), the cost per case/episode of care represented an itemized fee for service (FFS) corresponding to specific ICD-9 codes (or ICD-10 equivalent).

The ICD-9 codes were mapped to AIS scores using the ICDPIC-R open-access program. This method has previously been discussed in the specialty literature (Clark et al. 2018). Mapping from ICD-9 codes was obviously not as accurate as AIS scoring from primary medical records, and might be more accurate if more recent versions of the AIS were applied,[30] but it appears to be a reasonable substitution when other methods are impractical or unavailable. ICD-10 codes were mapped to ICD-9 codes, by applying the open-access general equivalence mapping (GEM) tables.

Table B25. Costs of Outpatient Services (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
CHILDREN									
Injuries to Head	TC	35274.67	318.31	2199.19	131.37	365.22	179.91	445649.44	377.68
Injuries to Neck	TC	35274.67	318.31	2178.68	130.15	365.22	179.91	399860.34	338.88
Injuries to Thorax	TC	35274.67	318.31	2178.68	130.15	268.87	132.45	457811.92	387.99
Injuries to Abdomen	TC	35274.67	318.31	2178.68	130.15	268.87	132.45	446188.42	378.14
Injurie to UppExt	TC	35274.67	318.31	2178.68	130.15	273.33	134.65	406592.18	344.58
Injuries to LowExt	TC	35274.67	318.31	2178.68	130.15	315.96	155.65	434956.11	368.62
Injuries to Multiple Regions	TC	35274.67	318.31	2727.62	162.94	386.97	190.63	539803.83	457.48
Injuries to Unspecified Region	TC	35274.67	318.31	2182.10	130.35	309.58	152.50	431843.07	365.98
ADULTS									
Injuries to Head	TC	36455.91	328.97	2199.19	131.37	365.22	179.91	445649.44	377.68
Injuries to Neck	TC	36455.91	328.97	2178.68	130.15	365.22	179.91	399860.34	338.88
Injuries to Thorax	TC	36455.91	328.97	2178.68	130.15	268.87	132.45	457811.92	387.99
Injuries to Abdomen	TC	36455.91	328.97	2178.68	130.15	268.87	132.45	446188.42	378.14
Injurie to UppExt	TC	36455.91	328.97	2178.68	130.15	273.33	134.65	406592.18	344.58
Injuries to LowExt	TC	36455.91	328.97	2178.68	130.15	315.96	155.65	434956.11	368.62
Injuries to Multiple Regions	TC	36455.91	328.97	2727.62	162.94	386.97	190.63	539803.83	457.48
Injuries to Unspecified Region	TC	36455.91	328.97	2182.10	130.35	309.58	152.50	431843.07	365.98

* TC = Treatment Course (episode of care) in ambulatory settings.
Source: Authors' calculations, based on national regulations on medical tariffs and country-reported data.

Table B26. Costs of Acute Hospital Services, AIS 1-2 cases (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
CHILDREN									
Injuries to Head	HSA	68082.10	614.35	4398.37	262.75	962.26	474.02	891298.88	755.36
Injuries to Neck	HSA	67959.28	613.24	4357.35	260.30	796.54	392.38	799720.67	677.75
Injuries to Thorax	HSA	72884.73	657.69	4357.35	260.30	790.57	389.44	915623.84	775.98
Injuries to Abdomen	HSA	72884.73	657.69	4357.35	260.30	772.92	380.75	892376.84	756.28
Injurie to UppExt	HSA	65296.96	589.22	4357.35	260.30	662.83	326.52	813184.36	689.16
Injuries to LowExt	HSA	65296.96	589.22	4357.35	260.30	666.92	328.53	869912.21	737.24
Injuries to Unspecified Region	HSA	64710.86	583.93	4364.19	260.70	775.34	381.94	863686.13	731.96

30 ICDPIC-R does not use the newer 2005, 2008, and 2015 versions of the AIS.

Table B26 (CONT). Costs of Acute Hospital Services, AIS 1-2 cases (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
ADULTS									
Injuries to Head	HSA	68295.23	616.27	4398.37	262.75	962.26	474.02	891298.88	755.36
Injuries to Neck	HSA	68278.97	616.13	4357.35	260.30	796.54	392.38	799720.67	677.75
Injuries to Thorax	HSA	71703.49	647.03	4357.35	260.30	790.57	389.44	915623.84	775.98
Injuries to Abdomen	HSA	71703.49	647.03	4357.35	260.30	772.92	380.75	892376.84	756.28
Injurie to UppExt	HSA	65925.52	594.89	4357.35	260.30	662.83	326.52	813184.36	689.16
Injuries to LowExt	HSA	65925.52	594.89	4357.35	260.30	666.92	328.53	869912.21	737.24
Injuries to Unspecified Region	HSA	66523.36	600.28	4364.19	260.70	775.34	381.94	863686.13	731.96

*** HSA = Hospital Stay (episode of acute care)**
Source: Authors' calculations, based on national regulations on medical tariffs and country-reported data.

Table B27. Costs of Acute Hospital Services, AIS 3+ and Polytrauma Cases (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
CHILDREN									
Injuries to Head	HSA	108728.34	981.13	5403.50	322.79	2919.60	1438.23	2490493.85	2110.66
Injuries to Neck	HSA	99081.54	894.08	5867.85	350.53	2257.08	1111.86	2320354.19	1966.47
Injuries to Thorax	HSA	120894.76	1090.91	5959.55	356.01	1937.90	954.63	2570279.70	2178.28
Injuries to Abdomen	HSA	110514.66	997.24	6187.68	369.63	2039.90	1004.88	2320074.86	1966.23
Injuries to UppExt	HSA	76672.29	691.86	5730.95	342.35	1087.74	535.83	2190354.19	1856.30
Injuries to LowExt	HSA	87699.01	791.36	6254.74	373.64	1125.37	554.37	2397896.09	2032.18
Injuries to Unspecified Region	HSA	87740.04	791.73	5900.71	352.49	1849.59	933.30	2381575.48	2018.35
ADULTS									
Injuries to Head	HSA	109684.18	989.75	5403.50	322.79	2919.60	1438.23	2490493.85	2110.66
Injuries to Neck	HSA	101592.13	916.73	5867.85	350.53	2257.08	1111.86	2320354.19	1966.47
Injuries to Thorax	HSA	123405.35	1113.57	5959.55	356.01	1937.90	954.63	2570279.70	2178.28
Injuries to Abdomen	HSA	111432.19	1005.52	6187.68	369.63	2039.90	1004.88	2320074.86	1966.23
Injuries to UppExt	HSA	79684.99	719.05	5730.95	342.35	1087.74	535.83	2190354.19	1856.30
Injuries to LowExt	HSA	91127.13	822.30	6254.74	373.64	1125.37	554.37	2397896.09	2032.18
Injuries to Unspecified Region	HSA	90678.43	818.25	5900.71	352.49	1849.59	933.30	2381575.48	2018.35
Injuries to Multiple Regions	HSA	181217.52	1635.24	11801.42	704.98	3789.19	1866.60	4763150.84	4036.71

*** HSA – Hospital Stay (episode of acute care)**
Source: Authors' calculations, based on national regulations on medical tariffs and country-reported data.

Table B28. Costs of Rehabilitation Services, 1st Stage (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
CHILDREN									
Injuries to Head	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Neck	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Thorax	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Abdomen	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injurie to UppExt	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to LowExt	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Multiple Regions	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Unspecified Region	HSAR	414285.50	3738.36	-	-	-	-	-	-
ADULTS									
Injuries to Head	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Neck	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Thorax	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Abdomen	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injurie to UppExt	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to LowExt	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Multiple Regions	HSAR	414285.50	3738.36	-	-	-	-	-	-
Injuries to Unspecified Region	HSAR	414285.50	3738.36	-	-	-	-	-	-

*** HSSR = Hospital Stay (episode of subacute and rehabilitative care)**
Source: Authors' calculations, based on national regulations on medical tariffs and country-reported data.

Table B29. Costs of Subacute Hospital and Rehabilitation Services (Standardized for 2016)

	UNIT COST	KAZ		KGZ		TJK		UZB	
		LCU	INT USD	LCU	INT USD	LCU	INT USD	LCU	INT USD
CHILDREN									
Injuries to Head	HSAR	128616.00	1160.58	4900.94	292.77	1940.93	956.12	1690896.37	1433.01
Injuries to Neck	HSAR	128616.00	1160.58	5112.60	305.41	1526.81	752.12	1560037.43	1322.11
Injuries to Thorax	HSAR	128616.00	1160.58	5158.45	308.15	1364.24	672.04	1742951.77	1477.13
Injuries to Abdomen	HSAR	128616.00	1160.58	5272.52	314.97	1406.42	692.82	1606225.85	1361.25
Injurie to UppExt	HSAR	128616.00	1160.58	5044.15	301.32	875.28	431.17	1501769.27	1272.73
Injuries to LowExt	HSAR	128616.00	1160.58	5306.05	316.97	896.14	441.45	1633904.15	1384.71
Injuries to Multiple Regions	HSAR	128616.00	1160.58	11801.42	704.98	3789.19	1886.60	4763150.96	4036.71
Injuries to Unspecified Region	HSAR	128616.00	1160.58	5132.45	306.60	1334.97	657.62	1622630.81	1375.16
ADULTS									
Injuries to Head	HSAR	128616.00	1160.58	4900.94	292.77	1940.93	956.12	1690896.37	1433.01
Injuries to Neck	HSAR	128616.00	1160.58	5112.60	305.41	1526.81	752.12	1560037.43	1322.11
Injuries to Thorax	HSAR	128616.00	1160.58	5158.45	308.15	1364.24	672.04	1742951.77	1477.13
Injuries to Abdomen	HSAR	128616.00	1160.58	5272.52	314.97	1406.42	692.82	1606225.85	1361.25
Injurie to UppExt	HSAR	128616.00	1160.58	5044.15	301.32	875.28	431.17	1501769.27	1272.73
Injuries to LowExt	HSAR	128616.00	1160.58	5306.05	316.97	896.14	441.45	1633904.15	1384.71
Injuries to Multiple Regions	HSAR	128616.00	1160.58	11801.42	704.98	3789.19	1886.60	4763150.96	4036.71
Injuries to Unspecified Region	HSAR	128616.00	1160.58	5132.45	306.60	1334.97	657.62	1622630.81	1375.16

*** HSSR = Hospital Stay (episode of subacute and rehabilitative care)**
Source: Authors' calculations, based on national regulations on medical tariffs and country-reported data.

Financial Burden of Road Traffic Injuries on Households

This study assumed, based on scientific and operational research, that a financial burden greater than 10 percent is likely to be catastrophic for the household economy, meaning that it is likely to force the household to cut its consumption of other minimum needs and/or trigger productive asset sales or high levels of debt, which in turn leads to impoverishment. This 10 percent figure is somewhat arbitrary because this level may not be catastrophic for high-income or resilient households that can mobilize their assets to pay for treatment.

In the absence of data, we calculated the out-of-pocket (OOP) part of the health care cost per RTC casualty by applying the value of the OOP share of total health expenditure for 2016, retrieved from the World Bank databank.

Table B30. Total Annual Income per Household in Kyrgyzstan, 2016 Local Currency Unit

QUINTILE GROUP OF INCOME	MINIMUM	MAXIMUM	MEAN
1	3,450	120,350	86,333.89
2	120,430	168,747	145,328.54
3	168,776	220,770	194,233.02
4	220,800	290,100	252,937.07
5	290,350	2,151,860	397,400.56

Source: Country-reported data

Table B31. Total Annual Income per Household in Tajikistan, 2016 Local Currency Unit

DECILE GROUP OF INCOME	MEAN
Poorest 10%	3,948.00
Richest 10%	40,365.12

Source: Country-reported data

Table B32. Total Annual Income per Household in Kazakhstan, 2016 Local Currency Unit

DECILE GROUP OF INCOME	MEAN
Poorest 10%	747,495
Richest 10%	3,112,602

Source: Country-reported data

Table B33. Estimated OOP expenditure per RTC event in Three Central Asian Countries, 2016 Local Currency Unit

Kazakhstan	44,107.01
Kyrgyzstan	4,341.90
Tajikistan	903,67

Source: Authors' calculations

Target Year

The most recent year with RTC and RTI-related health care data that was available at both the national and/or the institutional level for these countries was 2016; therefore it was chosen to value the health care costs.

Currencies

Table B34. Local Currency Unit per International Dollar (2016)

LOCAL CURRENCY UNIT (LCU)	LCU PER INT$ (2016)
Kazakhstani Tenge	110.82
Kyrgyzstani Som	16.74
Uzbekistani Som	1179.96
Tajikistani Somoni	2.03

Source: World Bank Databank

APPENDIX C:
CALCULATING THE VALUE OF STATISTICAL LIFE, AND THE EFFECT OF RTI DALYS ON LONG-RUN ECONOMIC GROWTH

Value of Statistical Life

The value of statistical life (VSL) is the amount of money that a population is willing to pay to marginally reduce the risk of death. Viscusi and Masterman (2017) showed that VSL is positively correlated with income, and its income elasticity is smaller at high levels of income, and larger at lower levels. Exploiting this relationship between income and VSL, they proposed a simple strategy for imputing the VSL for countries where microdata are missing and a proper estimation of the VSL is therefore not possible.

Using 2015 data, Viscusi and Masterman (2017) state the equation

$$\mathrm{VSL}_{\mathrm{i},2015} = \mathrm{VSL}_{\mathrm{US},2015}\left(\frac{\mathrm{GNI}_{\mathrm{i},2015}}{\mathrm{GNI}_{\mathrm{US},2015}}\right)^{\eta}$$

which relates VSL and GNI in the US to the same quantities in country i, and η is VSL elasticity with respect to income.

We exploited this formula twice. First, we updated the US VSL from 2015 to 2019 by using

$$\mathrm{VSL}_{\mathrm{US},2019} = \mathrm{VSL}_{\mathrm{US},2015}\left(\frac{\mathrm{GNI}_{\mathrm{US},2019}}{\mathrm{GNI}_{\mathrm{US},2015}}\right)^{0.511}$$

where $\eta = 0.511$ is income elasticity in the US.

Next, we estimated the VSL for Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan in 2019 by means of

$$\mathrm{VSL}_{\mathrm{i},2019} = \mathrm{VSL}_{\mathrm{US},2019}\left(\frac{\mathrm{GNI}_{\mathrm{i},2019}}{\mathrm{GNI}_{\mathrm{US},2019}}\right)$$

assuming $\eta = 1$ as suggested in Viscusi and Masterman (2017).

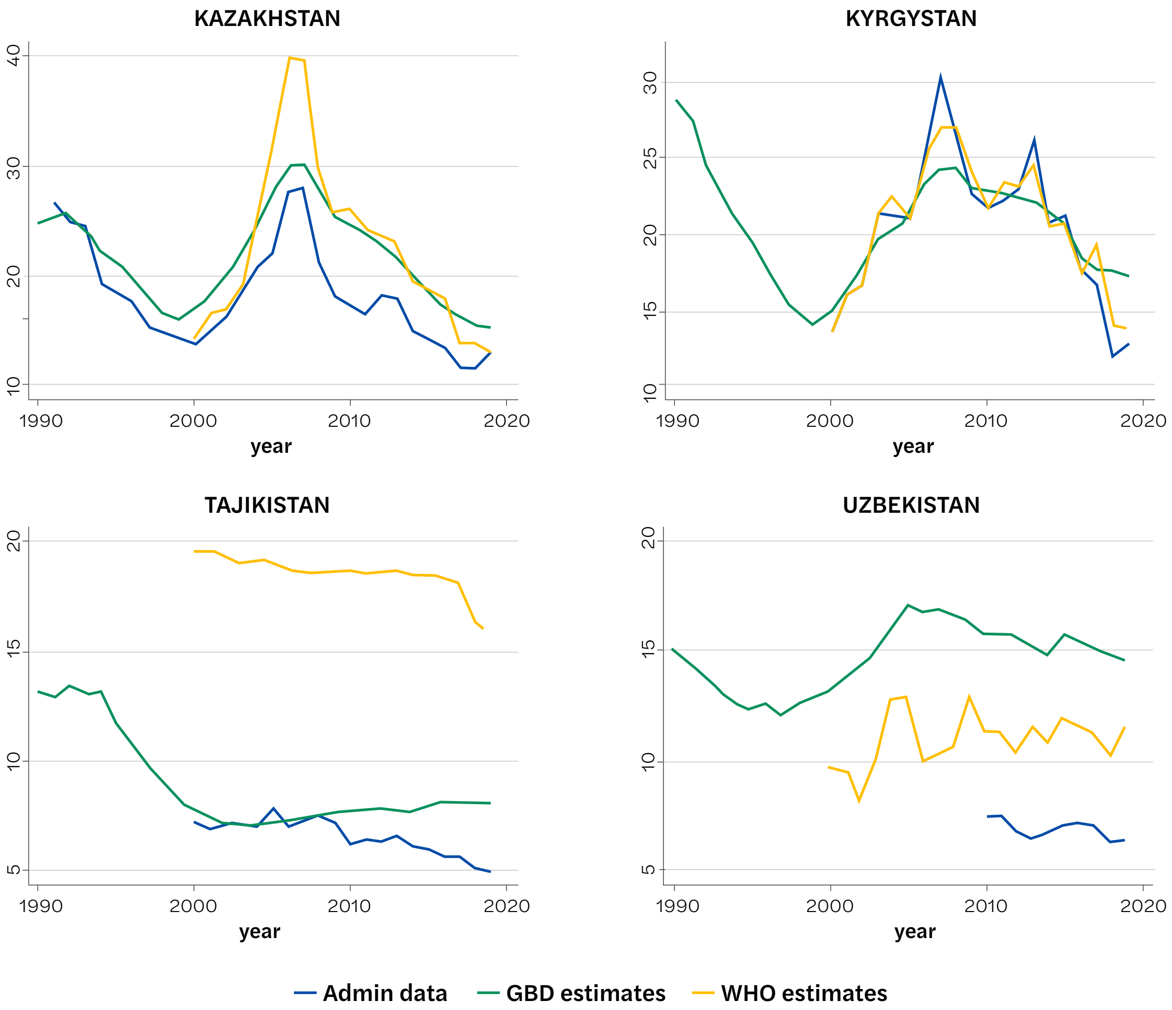
The Effect of RTI DALYs on Long-Run Economic Growth

To estimate the effect of RTI DALYs on economic growth we needed to address two problems. First, RTI DALYs (and all-cause DALYs more generally) are likely to be correlated with the characteristics of a country that are responsible for its economic development. But as long as some of these confounders are omitted from the model, the omitted variable bias may hide the true effect of RTI DALYs. To address this omitted variable bias we adopted the same strategy recently adopted in Rocco et al. (2021), which exploits methods of partial identification to establish bounds for the true effects.

Second, RT mortality and RT injuries are often poorly measured in developing countries, due to the underreporting of road accidents to the authorities and the misclassification of RTIs under other causes. The poor quality of RTI data is thus necessarily reflected in the DALYs measured and makes it difficult to estimate the effect of RTI DALYs on economic growth. Typically, error in variables produces attenuation bias; that is, estimates are biased toward zero.

To get an idea of the problem of data quality in the four countries under study, we compared RT mortality from three alternative sources; administrative data; and Global Burden of Disease (GBD) and WHO estimates from the WHO Global Health Observatory. (Figure C1). While in Kazakhstan and Kyrgyzstan administrative data are more or less aligned with international estimates, this is not the case for Tajikistan and Uzbekistan, where the administrative data differs substantially from WHO and GBD estimates. (Actually, in these two countries even the latter differs rather markedly.)

Figure C1. RTI Mortality



To circumvent the problem of measurement error, we proceeded indirectly, as detailed below. We exploited the fact that all-cause DALYs in the working age population are the sum of cause-specific DALYs. That is:

$$allcause\_DALY = \sum_{x} x\_DALY$$

Each cause-specific DALY, x_DALY, is affected by measurement error, x_ϑ, at least to some extent. However, the the combination of many independent measurement errors, $\sum_x x\_\vartheta$, is closer to zero, because independent errors cancel each other. Hence all-cause DALYs are less affected by measurement error than each cause-specific DALY.

The same reasoning applies to non-RTI DALYs in the working-age population; that is, DALYS from all causes but RTI, which is also the sum of many cause-specific DALYs.

$$nonRTI\_DALY = \sum_{x \neq RTI} x\_DALY$$

We separately estimated the effect of all-cause DALYs and the effect of non-RTI DALYs on economic growth, and then we derived the effect of RTI DALYs.

We proceeded as follows. We let long-run economic growth g_i depend on both RTI DALYs (*R*) and non-RTI DALYs (*NR*), and we let each component attract specific parameters α_R and α_{NR}:

$$g_i = \alpha_0 + \alpha_{NR} NR_i + \alpha_R R_i + \varepsilon_i \quad (1)$$

We divided and multiplied both variables by T, all-cause DALYs, and by rearranging the terms we rewrote model (1) as

$$g_i = \alpha_0 + [\alpha_{NR} + (\alpha_R - \alpha_{NR}) g_{Ri}] T_i + \varepsilon_i \quad (2)$$

where $g_{Ri} = \frac{R_i}{T_i}$ is the country-specific share of RTI DALYs (out of all-cause DALYs). Model (2) is equivalent to Model (1) but depends only on all-cause DALYS and on a country-specific parameter $[\alpha_{NR} + (\alpha_R - \alpha_{NR}) g_{Ri}]$ that captures the composition between RTI and non-RTI DALYs in country *i*.

Model (2) can be further rewritten as

$$g_i = \alpha_0 + \alpha_1 T_i + \{[\alpha_{NR} + (\alpha_R - \alpha_{NR}) g_{Ri} - \alpha_1] T_i + \varepsilon_i\} \quad (3)$$

where $\alpha_1 = \alpha_{NR} + (\alpha_R - \alpha_{NR})\overline{g_R}$ is the average of $[\alpha_{NR} + (\alpha_R - \alpha_{NR}) g_{Ri}]$ and $\overline{g_R}$ is the average of g_{Ri}.

Following Rocco et al. (2021), we estimated Model (3) via OLS (Ordinary Least Squares) and via 2SLS (Two-Stage Least Squares). In the second case all-cause DALYs were instrumented by the incidence of malaria falciparum prevailing in 1966 (Gallup et al., 1999), an instrumental variable also used in the seminal Lorentzen et al. (2008) paper. While this variable is largely predetermined, it likely does not meet the independence condition required for being a valid instrument, implying that even the 2SLS estimate is biased. Based on the results of Nevo and Rosen (2012), Rocco et al. (2021) showed that the true effect of all-cause DALYs is larger (in absolute value) than the largest (in absolute value) between the OLS and the 2SLS estimate. Accordingly, we took the largest (in absolute value) between the OLS and the 2SLS estimate as a conservative effect of T_i on economic growth.

The estimated α_1 captures

$$\hat{\alpha}_1 = \alpha_{NR} + (\alpha_R - \alpha_{NR})\overline{g_R} \quad (4)$$

Next, starting again from model (1), we specified the "short" model

$$g_i = \alpha_0 + \alpha_{NR} NR_i + (\alpha_R R_i + \varepsilon_i) \quad (5)$$

where R_i is omitted from the set of regressors and left in the error term. If Model (1) is correctly specified, Model (4) is necessarily mis-specified and generates an omitted variable bias. The estimated $\hat{\alpha}_{NR}$ is

$$\hat{\alpha}_{NR} = \alpha_{NR} + \alpha_R \frac{cov(R_i, NR_i)}{Var(NR_i)} = \alpha_{NR} + \alpha_R \lambda_{OLS} \text{ (6a)}$$

if (5) is estimated by OLS, and

$$\hat{\alpha}_{NR} = \alpha_{NR} + \alpha_R \frac{cov(R_i, Z_i)}{cov(NR_i, Z_i)} = \alpha_{NR} + \alpha_R \lambda_{2SLS} \text{ (6b)}$$

if (5) is estimated by 2SLS.

We therefore had two linear equations and two unknowns that could be solved to obtain

$$\alpha_R = \frac{\hat{\alpha}_1 - (1 - \overline{g_R})\hat{\alpha}_{NR}}{\overline{g_R} - \lambda(1 - \overline{g_R})} \quad (7)$$

and

$$\alpha_{NR} = \hat{\alpha}_{NR} - \lambda \frac{\hat{\alpha}_1 - (1 - \overline{g_R})\hat{\alpha}_{NR}}{\overline{g_R} - \lambda(1 - \overline{g_R})} \quad (8)$$

which are the estimates of the effects of RTI DALYs and nonRTI DALYs respectively.

We operationalized g_i as the percent change between real GDP per capita in 2019 and 1990, and T_i and NR_i as the average all-cause DALYs and non-RTI DALYs in the same period, as in both Lorentzen et al. (2008) and Rocco et al. (2021). We added a number of controls, which are listed in Table C1 along with their summary statistics. All models were controlled for the logarithm of per-capita GDP in 1990; the initial condition; and the share of the population aged 65 and over in 1990, which we interpreted as an indicator of the stage of the demographic transition at the beginning of the period;
the average between 1990 and 2019 of the country population (in logarithm); the proportion of urban residents; the proportion of residents with internet access; government spending; an index of openness to the global economy (defined as the ratio between the sum of imports and exports and national GDP); human capital (proxied by the share of population with at least secondary education); social capital (the share of the population reporting that they trust other people from the World Values Survey (WVS); and a proxy of institutional quality (an index of civil liberties from Freedom House). We also added a set of variables accounting for the proportion of the country's area that is in polar, boreal, humid temperate, dry temperate, subtropical, and tropical zones.

Table C1. Summary Statistics

VARIABLE	OBS	MEAN	STD. DEV.	MIN	MAX
Growth 1990-2019	136	88.8507	100.4279	-57.67975	608.0521
RTI DALYs age 15-64	136	1374.539	754.4503	398.6714	5082.055
Non-RTI DALYs age 15-64	136	30374.42	12689.95	15606.51	82330.54
All-Cause DALYs age 15-64	136	31748.96	12952.75	16005.18	85013.84
CONTROLS					
Log GDPpc 1990	136	8.780256	1.201841	6.00496	11.53461
Population 65+ 1990	136	6.36266	4.204181	1.200099	17.82374
Log population	136	16.42661	1.36333	14.0792	20.97628
Civil Liberties	136	3.421324	1.705401	1	7
Urban Population	136	55.50004	21.50142	9.455733	100
Internet	136	21.84047	16.71528	.6994352	61.85134
Public Spending	136	.1846297	.0677691	.0217823	.4921883
Openness	136	.5012355	.4255278	.0799012	3.439682
Secondary Education	136	47.87848	25.62227	0	95.72875
Trust	136	16.53584	16.72448	0	73.9
Polar	136	.0170619	.0557763	0	.3031908
Boreal	136	.0642802	.1586313	0	.9105653
Dry-Temp	136	.0955475	.1827708	0	.838334
Wet-Temp	136	.2084851	.3253703	0	1
Subtropical	136	.2831337	.3301978	0	.9805556
Tropical	136	.1643917	.2610961	0	1
INSTRUMENT					
Incidence of malaria falciparum 1966	136	32.41507	42.40337	0	100

Tables C2 and C3 report estimates for Models (3) and (5), by applying OLS or 2SLS respectively. They also report the corresponding Oster (2019) estimates. Oster provides a strategy for addressing the problem of omitted variables. Under the assumption that omitted variables are as important as the included controls in explaining T_i, and under the additional assumption that adding omitted variables will increase the model's R-squared by 30 percent, it is possible to gauge the effect of interest net of the omitted variable bias. Considering OLS estimates, the effect of T_i increases (in absolute value) from 0.00266 to 0.00345. Turning to the reduced form and the first stage of the 2SLS estimator (Columns 3 and 4 in Table C2), we find that the inclusion of unobservables increases the reduced form (in absolute value) and decreases the first stage. This implies that the 2SLS estimate (which is the ratio between the reduced form and the first-stage estimates) would be larger (in absolute value) if the omitted variables were accounted for. Together these results (about OLS and 2SLS) confirm the finding in Rocco et al. (2021) that the correlation between T_i and the regression error term ε is positive, as well as the correlation between Z_i (the instrumental variable) and the error term ε.

Finally, the correlation between T_i and Z_i is also positive, as the first-stage estimate of Tables C2 and C3 (Column 3) reveals. Under these conditions, Nevo and Rosen (2012) proved that the true effect of T_i on g_i is larger (in absolute value) than the largest estimate between the OLS and the 2SLS estimate, or $\alpha_1 < \min(\hat{\alpha}_{1,OLS}, \hat{\alpha}_{1,2SLS})$.

For both all-cause DALYs and non-RTI DALYs we found that 2SLS estimates were larger than OLS in absolute value. We took the former as conservative values for $\hat{\alpha}_1$ and $\hat{\alpha}_{NR}$ which turned out to be -0.00400 and -0.00422 respectively. In terms of semi-elasticities, a reduction of all-cause DALYs by 1 percent would increase long-run GDP growth of 1.27 percentage points on average. Similarly, a reduction of non-RTI DALYs by 1 percent would increase long-run growth of 1.28 percentage points on average.

Applying equation (7) and bootstrapping, we obtained that the effect of RTI DALYs is $\alpha_R = -0.0040038$ (std. err. = 0.0023494) (p.val. = 0.088).

Table C2. The Effect of All-Cause DALYs in the Working-Age Population on Long-Run Economic Growth

	(1) OLS	(2) 2SLS	(3) REDUCED FORM	(4) FIRST STAGE
All-cause DALYs in the working-age population	-0.00266***	-0.00400**		
	(0.000803)	(0.00192)		
Incidence of Malaria Falciparum 1966			-0.631*	157.7***
			(0.322)	(31.08)
Observations	136	136	136	136
R-squared	0.376	0.361	0.338	0.565
semi-elasticity	-0.845	-1.271		
Oster's estimate	-0.00345		-0.828	39.29
F		25.74		

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All models include the controls listed in Table C1.

Table C3. The Effect of Non-RTI DALYs in the Working-Age Population on Long-Run Economic Growth

VARIABLES	(1) OLS	(2) 2SLS	(3) REDUCED FORM	(4) FIRST STAGE
NonRTI DALYs in the working-age population	-0.00274***	-0.00422**		
	(0.000835)	(0.00203)		
Incidence of Malaria Falciparum 1966			-0.631*	157.7***
			(0.322)	(31.08)
Observations	136	136	136	136
R-squared	0.377	0.359	0.338	0.565
semi-elasticity	-0.833	-1.282		
Oster's estimate	-0.00358		-0.828	34.17
F		22.71		

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All models include the controls listed in Table C1.

The same procedure can be applied for RTI mortality. The true effect of all-cause mortality is bounded above by -0.207 and the true effect of non-RTI mortality is bounded above by -0.217. In semi-elasticity, a reduction in both types of mortality by 1 percent will increase long-run economic growth by 0.96 percentage points. Applying equation (7) and bootstrapping, we obtained that the effect of RTI morality is α_R=−0.207046 (std. err. = 0.12185) (p.val. = 0.089).

Table C4. The Effect of All-Cause Mortality in the Working-Age Population on Long-Run Economic Growth

	(1) OLS	(2) 2SLS	(3) REDUCED FORM	(4) FIRST STAGE
All-cause DALYs in the working-age population	-0.121***	-0.207**		
	(0.0395)	(0.0996)		
Incidence of Malaria Falciparum 1966			-0.631*	3.049***
			(0.322)	(0.598)
Observations	136	136	136	136
R-squared	0.365	0.340	0.338	0.569
semi-elasticity	-0.565	-0.963		
Oster's estimate	-0.164		-0.828	1.164
F		26.04		

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All models include the controls listed in Table C1.

Table C5. The Effect of All-Cause Mortality in the Working-Age Population on Long-Run Economic Growth

	(1) OLS	(2) 2SLS	(3) REDUCED FORM	(4) FIRST STAGE
Non-RTI mortality in the working-age population	-0.125***	-0.217**		
	(0.0412)	(0.105)		
Incidence of Malaria Falciparum 1966			-0.631*	2.911***
			(0.322)	(0.601)
Observations	136	136	136	136
R-squared	0.365	0.337	0.338	0.572
semi-elasticity	-0.553	-0.961		
Oster's estimate	-0.170		-0.828	1.064
F		23.44		

Note: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. All models include the controls listed in Table C1.

Given the estimated α_R we can predict the additional income per capita in 2048, assuming that the same relationship between DALYs and long-run economic growth holds stable in the future.

Model (1) implies that

$$\frac{y_{i,2048}-y_{i,2019}}{y_{i,2019}} \times 100 = \alpha_0 + \alpha_{NR} NR_{i,2019} + \alpha_R R_{i,2019} \quad (9)$$

The effect of a change in RTI DALYs, $R_{i,2019}$, on $y_{i,2048}$ is

$$dy_{i,2048} = \alpha_R y_{i,2019} dR_{i,2019}/100 \quad (10)$$

The Net Present Value (NPV) of GDP per-capita growth between 2019 and 2048, assuming that $dy_{i,2048}$ is accrued linearly over the 30 years period, is

$$NPV = \sum_{t=2019}^{2048} \left[\frac{1}{(1+\delta)^{t-2019}} \frac{dy_{i,2048}}{30} (t - 2019 + 1) \right] \quad (11)$$

where δ is the annual discount factor (assumed to be 2 percent).

In the main text we have estimated the effect of reducing 2019 RTI DALYs by 10 percent, i.e. $dR_{i,2019} = -0.1 R_{i,2019}$. Equation (11) is linear in $dy_{i,2048}$ and in turn in $dR_{i,2019}$. This allows the benefits of alternative policies to be evaluated with the use of simple computations. For instance, the progressive reduction of RTI DALYs to 50 percent of its 2019 level by 2029, followed by two decades of RTI DALYs stable at the achieved lower levels, amounts to set $dR_{i,2019} = -0.41 R_{i,2019}$. Indeed, under this policy, the average RTI DALYs over the period 2019-48 would be 41 percent lower than its level in 2019.

APPENDIX D:
ROAD SAFETY INTERVENTIONS IMPLEMENTED IN LMICS

Table D1: Examples of Proven and Promising Road Safety Interventions Implemented in LMICs

INTERVENTIONS PROVEN IN HIGH-INCOME COUNTRIES (HICS)	IMPLEMENTATION AND EVALUATION IN LMICS		
	COUNTRY	STUDY DESIGN	RESULTS
Providing and encouraging use of alternative forms of mass transportation	Guadalajara, Mexico	Before-and-after study of the impact of Macrobus on crashes.	46 percent reduction in crashes after Macrobus was implemented.
Increasing the visibility of pedestrians and cyclists	Seremban and Shah Alam, Malaysia	Time-series study of the use of daytime running lights for motorcycles.	29 percent reduction in visibility-related motorcycle crashes.
Supervising children walking to school	Kuala Teregganu, Malaysia	Case-control study assessing the risk of injury to children walking or cycling to school who were supervised by parents	Risk of injury was reduced by 57 percent among supervised children.
Separating different types of road users	Selagor, Malaysia	Video observational study of crashes and outcomes after the introduction of an exclusive motorcycle lane.	39 percent reduction in motorcycle crashes, and 600 percent decrease in fatalities
Reducing average speeds-through traffic calming measures	China	Before-and-after study of simple engineering measures (such as speed humps, raised intersections, and crosswalks) on speed and casualties	Average speed dropped by 9 percent in three of four intervention sites; overall number of casualties dropped by 60 percent.
Setting and enforcing speed limits appropriate to the function of roads	Londrina, Brazil	Time-series study on enforcement of speed control, seat belt use, new traffic code, and improved prehospital care.	Reduction in mortality to 27.2 per 100,000 population after one year of implementing a new traffic code.
Setting and enforcing blood alcohol concentration limits	Kampala, Uganda	Time-series study on enforcement of alcohol-impaired driving and speed laws	17 percent reduction in traffic fatalities after intervention
	Villa Clara, Cuba	Time-series study on enforcement of alcohol-impaired driving during weekends	9.9 percent reduction in traffic crashes, 70.8 per cent reduction in deaths, and 58.7 percent reduction in injuries, compared with the previous year (2002).

INTERVENTIONS PROVEN IN HIGH-INCOME COUNTRIES (HICS)	IMPLEMENTATION AND EVALUATION IN LMICS		
	COUNTRY	STUDY DESIGN	RESULTS
Setting and enforcing the use of seat belts for all motor vehicle occupants	Iran, Islamic Republic	Before-and-after study of seat belt and helmet enforcement and social marketing.	Death rates reduced from 38.2 per 100,000 population in 2004 to 31.8 in 2007 ($p < 0.001$); death rate per 10,000 vehicles reduced from 24.2 to 13.4.
	Guangzhou, China	Before-and-after study of enhanced enforcement and social marketing on seat belt wearing.	12 percent increase in prevalence of seat belt use ($p = 0.001$).
Setting and enforcing motorcycle helmet use	Cali, Colombia	Time-series analysis of fatalities following implementation of mandatory helmet law, reflective vests, restrictions on when motorcycles can be used, and compulsory drivers' training.	52 percent reduction in motorcyclist deaths.
	Thailand	Before-and-after survey using trauma registry data following implementation of helmet law.	Helmet use increased five-fold, injuries decreased by 41 percent, and deaths decreased by 20.8 percent.
	Vietnam	Time-series observational study in three provinces following introduction of mandatory motorcycle helmet law.	16 percent reduction in injuries, and 18 percent reduction in deaths.
	Malaysia	Time-series study of motorcycle-related crashes, injuries, and fatalities following implementation of a Motorcycle Safety Program using annual police statistics.	25 percent reduction in motorcycle-related crashes, 27 percent reduction in motorcycle-related casualties, and 35 percent reduction in motorcycle fatalities.
Encouraging helmet use among child bicycle riders	Czech Republic	Case-control study of helmet enforcement, education, and reward campaign at schools	100 percent increase in helmet use, and 75 percent reduction in head injury admission rates

Source: Based on Bachani et al. 2017

Table D2: Single Interventions for Specific Unintentional Injuries

	Outcome	Country	Minimum effect (RR)	Maximum effect (RR)
Road traffic				
Enforcement				
Enforcement of speed cameras[22]	Injuries	Multiple countries	··	0·79 (0·78–0·80)
Seat-belt enforcement[23]	Mortality	USA	··	0·89
Random breath testing[24]	Mortality	Multiple countries	0·52	0·86
Random breath testing[24]	Injuries	USA	0·76	0·87
Selective breath testing[24,25]	Mortality	USA	0·80 (0·77–0·95)	0·80
Selective breath testing[24]	Injuries	USA	0·79	0·81
Traffic enforcement[26]	Mortality	Uganda	··	0·73 (0·51–0·94)
Drink-driving enforcement[27]	Mortality	Cuba	··	0·30
Drink-driving enforcement[27]	Injuries	Cuba	··	0·42
Drink-driving enforcement[28]	Crashes	Multiple countries	0·70	0·85 (0·83–0·89)
Speed enforcement detection devices[29,30]	Crashes	Multiple countries	0·28	0·84
Speed enforcement detection devices[29,30]	Injuries	Multiple countries	0·54	0·92
Speed enforcement detection devices[29,30]	Mortality	Multiple countries	0·55	0·60
Red-light cameras[31]	Crashes	Multiple countries	0·71 (0·55–0·93)	0·87 (0·77–0·98)
Speed cameras[32]	Crashes	Multiple countries	0·31	0·95
Speed cameras[31,32]	Injuries	Multiple countries	0·35	0·82
Speed cameras[32]	Mortality	Multiple countries	0·29	0·83
Speed cameras[33]	Crashes	Multiple countries	0·51	0·92
Speed cameras[33]	Mortality and serious injuries	Multiple countries	0·56	0·89
Average speed enforcement[34]	Mortality and serious injuries	Multiple countries	0·15	0·67
Device effectiveness				
Bicycle helmet use[35]	Head injury	USA	··	0·15 (0·07–0·29)
Helmet use[30]	Head injury	Multiple countries	··	0·28 (0·23–0·35)
Helmet use[30]	Mortality	Multiple countries	0·03 (0·01–0·42)	0·61 (0·54–0·70)
Rear-seat seat-belt use[36]	Mortality	USA	··	0·42 (0·38–0·46)
Correct child safety seat in short term[37]	Correct use in short term	Multiple countries	··	1·22 (1·04–1·62)
Correct child safety seat in long term[37]	Correct use in long term	Multiple countries	··	1·06 (1·02–1·07)
Community				
Drink-driving awareness campaigns for 6 months[38]	Crashes	Multiple countries	··	0·87 (0·86–0·94)
Road safety campaigns[39]	Crashes	Multiple countries	··	0·91 (0·88–0·94)
Promoting bicycle helmet wearing[40]	Helmet wearing	Multiple countries	··	2·13 (1·35–3·35)
Community-based intervention promoting bicycle helmet wearing[40]	Observed bicycle helmet wearing	Multiple countries	··	4·57 (2·37–8·81)
Behavioural interventions for children's pedestrian safety[41]	Pedestrian safety	Multiple countries	2·88 (1·89–4·39)	3·44 (2·06–5·75)
Overall impact of safety initiatives in Malaysia[42]	Mortality	Malaysia	··	0·78
Infrastructure				
Overpass or underpass[43]	Injuries	Multiple countries	··	0·09
Roadway lighting[43]	Pedestrian-vehicle crashes	Multiple countries	··	0·41
Traffic calming[43]	Pedestrian-vehicle crashes	Multiple countries	··	0·25
Traffic calming[44]	Injuries	Multiple countries	··	0·85
Multiway stop signs[43]	Crashes	Multiple countries	··	0·75
Roadway lighting[43]	Pedestrian-vehicle crashes	Multiple countries	··	0·41
Roundabouts[43]	Pedestrian crashes	Multiple countries	··	0·25
Law and legislation				
Vehicle safety measures[45]	Mortality	France	··	0·89
Helmet-use law[46]	Mortality	Colombia	··	0·88
Helmet-use law[47]	Head injury	Vietnam	··	0·84 (0·81–0·87)
Helmet-use law[47]	Mortality	Vietnam	··	0·82 (0·73–0·93)
Graduated driver license programmes[48,49]	Crashes	Multiple countries	0·69	0·85 (0·73–0·92)
Raising the minimum legal drinking age[25]	Injuries	Multiple countries	··	0·85 (0·67–0·94)
Raising the minimum legal drinking age[25]	Mortality	Multiple countries	··	0·83 (0·80–0·89)
Raising the minimum legal drinking age by 3 years[25]	Mortality	Multiple countries	··	0·88 (0·87–0·92)
Seat-belt law[50]	Mortality	USA	··	0·97
Zero-tolerance laws[50]	Mortality	USA	··	0·95
3% increase in taxes on beer[50]	Mortality	USA	··	0·63
Interventions in the alcohol-server setting[51]	Crashes	Multiple countries	··	0·48 (0·04–0·89)
Interventions in the alcohol-server setting[51]	Injuries	Multiple countries	··	0·85
Interventions in the alcohol-server setting[51]	Assault	Multiple countries	··	0·48
Interventions in the alcohol-server setting[51]	Police-reported violence	Multiple countries	··	0·71
Graduated driver licensing[25]	Crashes	USA	0·60	0·80
Reduction of BAC from 0·01 to 0·08 units[52]	Mortality	USA	0·84	0·95
Reduction of BAC from 0·08 to 0·05 units[52]	Mortality	USA	0·82	0·94

Source: Vecino-Ortiz et al. 2018

Table D3: Packages of Unintentional Injury Interventions Found Through Literature Review

	Outcome	Country	Minimum effect (RR)	Maximum effect (RR)
Road traffic				
Child safety seat distribution and education programmes[7]	Injuries	Multiple countries	..	0·94
Legislation, police enforcement, and social-marketing campaigns[62]	Seatbelt use among drivers	Russia	..	1·19
Legislation, police enforcement, and social-marketing campaigns[62]	Seatbelt use among front-seat passengers	Russia	..	1·42
Legislation, police enforcement, and social-marketing campaigns[62]	Seatbelt use among rear-seat passengers	Russia	..	1·22
Legislation, police enforcement, and social-marketing campaigns[62]	Child-restraint use	Russia	..	1·20
Legislation, police enforcement, and social-marketing campaigns[62]	Speeding	Russia	..	0·24
Legislation, police enforcement, and social-marketing campaigns[63]	Crashes	Ethiopia	..	0·81
Legislation, police enforcement, and social-marketing campaigns[63]	Mortality	Ethiopia	..	0·88
Drink-drive legislation and enforcement[23]	Long-term non-fatal road traffic injury	Multiple countries	..	0·75
Drink-drive legislation and enforcement[23]	Mortality	Multiple countries	..	0·85
Legislation and enforcement of helmets[23]	Long-term non-fatal road traffic injury	Multiple countries	..	0·77
Legislation and enforcement of helmets[23]	Mortality	Multiple countries	..	0·64
Legislation and enforcement of helmets for bicyclists aged <15 years[64]	Long-term non-fatal road traffic injury	Multiple countries	..	0·60 (0·45–0·71)
Legislation and enforcement of helmets for bicyclists aged <15 years[64]	Mortality	Multiple countries	..	0·31 (0·69–0·90)
Traffic safety intervention[65]*	Mortality	Malaysia	..	0·90 (0·054)
Enhanced training and enforcement practices along with raising of public awareness[66]	Seatbelt use	China	..	1·12 (1·12–1·13)
Enforcement of laws on the mandatory fastening of seat-belts, enforcement of the laws on use of motorcycle helmets and general traffic laws, and mass-media educational campaigns on national radio and television[67]	Mortality	Iran	..	0·83 (0·82–0·85)
Low-cost engineering measures[68]†	Injuries	Portugal	..	0·90
Area-wide traffic-calming measures[69]	Injuries	Portugal	..	0·89 (0·80–1·00)
Comprehensive motorcycle helmet policy[70]	Mortality	Vietnam	..	0·71 (0·63–0·84)
Comprehensive motorcycle helmet policy[70]	Head injuries	Vietnam	..	0·54 (0·23–0·82)

Source: Vecino-Ortiz et al. 2018

BIBLIOGRAPHY

Aarts L.T., J.J. F. Commandeur, R. Welsh, S.Niesen, M. Lerner, P. Thomas, N. Bos, R. J. Davidse. 2016. "Study on Serious Road Traffic Injuries in the EU." Brussels: European Commission. doi:10.2832/29647

Abdunazarov, J., K. Azizov, and I. Shukurov. 2020. "Method of Analysis of the Reasons and Consequences of Traffic Accidents in Uzbekistan Cities." *International Journal of Safety and Security Engineering* 10 (4): 483-90.

ADB (Asian Development Bank). 2016. "Safely Connected: A Regional Road Safety Strategy for CAREC Countries, 2017–2030." Endorsed at the 15th CAREC Ministerial Conference, Islamabad, Pakistan. October (Vol. 26).

Araujo, M., E. Illanes, E. Chapman, and E. Rodrigues. 2017. "Effectiveness of Interventions to Prevent Motorcycle Injuries: A Systematic Review of the Literature." *International Journal of Injury Control and Safety Promotion* 24 (3): 406-22.

Arleth, T., S.S. Rudolph, C. Svane, and L. S. Rasmussen. 2020."Time from Injury to Arrival at the Trauma Center in Patients Undergoing Interhospital Transfer." *Danish Medical Journal* 67 (9): A03200138

Artikova, V., M.E. Thompson, E. Platonova, G. F. Pyle,S. Toimatov. 2011. "Trends in Traffic Collisions and Injuries in Kyrgyzstan, 2003–2007." *Bulletin of the World Health Organization.* 89: 345–51 doi:10.2471/BLT.10.084434

Bachani, A.M., M. Peden, G. Gururaj, R. Norton, and A. A. Hyder. 2017. "Road Traffic Injuries." In *Injury Prevention and Environmental Health. Disease Control Priorities.* 3rd edition, Volume 7. Edited by C.N. Mock et al. Washington DC: World Bank. 35-54.

Barell, V., L. Aharonson-Daniel, L. A. Fingerhut, E.J. Mackenzi, A. Ziv, V. Boyk, A. Abargel, M. Avitzour, R. Heruti. 2002. "An Introduction to the Barell Body Region by Nature of Injury Diagnosis Matrix." *Injury Prevention* 8 (2): 91-96. doi:10.1136/ip.8.2.91

Bhalla, K., M. Ezzati, A. Mahal, J. Salomon, and M. Reich. 2007. "A Risk-Based Method for Modeling Traffic Fatalities." *Risk Analysis.* 27 (1): 125-36. doi: 10.1111/j.1539-6924.2006.00864.x. PMID: 17362405.

Bhalla, K., S. Sharaz, J.P. Abraham, D. Bartels, and P.H. Yeh. 2011. "Road Injuries in 18 Countries." Boston: Department of Global Health and Population, Harvard School of Public Health.

Bickel P., R. Friedrich, A. Burgess, P. Fagiani, A. Hunt, G. De Jong, J. Laird, C. Lieb, G. Lindberg, P. Mackie, S. Navrud, T. Odgaard, A. Ricci, J. Shires, and L. Tavasszy. 2006. HEATCO Deliverable 5, Proposal for Harmonized Guidelines. Stuttgart: University of Stuttgart.

Bloom, D.E., M. Kuhn, and K. Prettner. 2019. *Health and Economic Growth*. Oxford Research Encyclopaedia, Economics and Finance https://doi.org/10.1093/acrefore/9780190625979.013.3

Bohman, K., H. Stigson, and M. Krafft. 2014. "Long-Term Medical Consequences for Child Occupants 0 to 12 Years Injured in Car Crashes." *Traffic Injury Prevention 15 (4): 370–78.*

Bolen J., D.A. Sleet, and V. Johnson. 1997. "Overview of Efforts to Prevent Motor Vehicle-Related Injury." In Bolen, J., D.A. Sleet, and V. Johnson, eds. *Prevention of Motor Vehicle-Related Injuries: A Compendium of Articles from the Morbidity and Mortality Weekly Report, 1985–1996*. Atlanta: Centers for Disease Control and Prevention.

Bonnet, E., L. Lechat, V. Ridde. 2018. "What Interventions Are Required to Reduce Road Traffic Injuries in Africa? A Scoping Review of the Literature." PLoS ONE. 13 (11): e208195.

Brown, S., A. R. Hole, and D. Kilic. 2014. "Out-of-Pocket Health Care Expenditure in Turkey: Analysis of the 2003–2008 Household Budget Surveys." *Economic Modelling 41: 211–18.*

Butcher N., and Z.J. Balogh. 2012. "AIS>2 in at Least Two Body Regions: A Potential New Anatomical Definition of Polytrauma." *Injury.* 43 (2): 196-99. doi: 10.1016/j.injury.2011.06.029. Epub 2011 Jul 13. PMID: 21741649

Chisholm D., H. Naci, A.A. Hyder, N.T. Tran, and M. Peden. 2012. "Cost Effectiveness of Strategies to Combat Road Traffic Injuries in Sub-Saharan Africa and South East Asia: Mathematical Modelling Study." *Bmj.* (March 2): 344.

Clark, D. E., A. W. Black, D.H. Skavdahl, and L.D. Hallagan. 2018. "Open-Access Programs for Injury Categorization Using ICD-9 or ICD-10." *Injury Epidemiology* 5 (11). https://doi.org/10.1186/s40621-018-0149-8

Du, R.Y., M.A. LoPresti, R. M. García, and S. Lam. 2020. "Primary Prevention of Road Traffic Accident-Related Traumatic Brain Injuries in Younger Populations: A Systematic Review of Helmet Legislation." *Journal of Neurosurgery: Pediatrics* 25 (4): 361-74.

Falkingham, J. 2004. "Poverty, Out-of-Pocket Payments and Access to Health Care: Evidence from Tajikistan." *Social Science & Medicine* 58: 247–58.

Forman, J., G.S. Poplin, C.G. Shaw, T. L. McMurry, K. Schmidt, J. Ash, C. Sunnevang. 2019. "Automobile Injury Trends in the Contemporary Fleet: Belted Occupants in Frontal Collisions." *Traffic Injury Prevention* 20 (6): 607-12, DOI: 10.1080/15389588.2019.1630825.

Gallup, J.L., J. D. Sachs, and A. Mellinger. 1999. Geography and Economic Development, CID Working Paper No. 1 March 1999

Gertler, P., and J. Gruber. 2002. "Insuring Consumption Against Illness." *American Economic Review* 92 (1): 51–70.

Gupta, M., and S. Bandyopadhyay. 2020. "Regulatory and Road Engineering Interventions for Preventing Road Traffic Injuries and Fatalities Among Vulnerable Road Users in Low and Middle-Income Countries: A Systematic Review." *Frontiers in Sustainable Cities* (May 19) 2: 10.

Hamada, S. R., N. Delhaye, S. Degoul, T. Gauss, M. Raux, M. L. Devaud, J. Amani, F. Cook, C. Hego, J. Duranteau, A. Rouquette, and Traumabase Group. 2019. "Direct Transport vs. Secondary Transfer to Level I Trauma Centers in a French Exclusive Trauma System: Impact on Mortality and Determinants of Triage on Road-Traffic Victims." PLoS ONE 14 (11): e0223809. https://doi.org/10.1371/journal.pone.0223809

Hanna, R. 2010. "Children Injured in Motor Vehicle Traffic Crashes." NHTSA (National Highway Traffic Safety Administration) Technical Report.

International Harmonization Research Activities Pedestrian Safety Working Group. Pedestrian Traffic Accident Data http://www.unece.org/trans/doc/2003/wp29grsp/ps-31.doc (Accessed on December 8, 2020)

Jurewich, C. et al. 2016. "Exploration of Vehicle Impact Speed: Injury Severity Relationships for Application in Safer Road Design." *Transportation Research Procedia*. 14: 4247-56.

Kassam, F. and H. Merali. 2019. "Addressing Road Traffic Injuries in Low- and Middle-Income Countries: A Kingdon Policy Analysis." *The Columbia Journal of Global Health*. 9 (1).

Kasnatscheew, A., F. Heinl, S. Schoenebeck, M. Lerner, and P. Hosta. 2016. *Review of European Accident Cost Calculation Methods – With Regard to Vulnerable Road Users*. Deliverable 5.1 of the InDeV Project.

Lawrence, B., and T. Miller. 2014. "Medical and Work Loss Cost Estimation Methods for the WISQARS Cost of Injury Module." Calverton : Pacific Institute for Research and Evaluation.

Lefio, Á., V.C. Bachelet, R. Jiménez-Paneque, P. Gomolán, and K. Rivas. 2018. "A Systematic Review of the Effectiveness of Interventions to Reduce Motor Vehicle Crashes and Their Injuries Among the General and Working Populations." *Rev Panam Salud Publica*. (May 4) 42: e60. doi: 10.26633/RPSP.2018.60. PMID: 31093088; PMCID: PMC6386148.

Liu et al. 2007. "Characteristics of Crash Injuries Among Young, Middle-Aged, and Older Drivers."

NHTSA Technical Report.

Lorentzen, P., J. McMillan, and R. Wacziarg. 2008. "Death and Development." *Journal of Economic Growth* 13: 81-124.

Malczyk, A., and T. Strauss. 2015. "Bicyclist Injury Patterns in Collisions with Motor-Vehicles." Hannover, Germany: ICSC (International Cycling Safety Conference).

Malczyk, A., and J. Bende. 2019. "Heavy Truck Crashes Involving Pedestrians in Comparison to Bicyclists." Paper Number 19-0080-W. 26th International Technical Conference on the Enhanced Safety of Vehicles. Eindhoven.

Malm, S., M. Krafft, A. Kullgren, A. Ydenius, C. Tingvall. 2008. "Risk of Permanent Medical Impairment (RPMI) in Road Traffic Accidents." Annals of Advances in Automotive Medicine 52: 93–100.

Martin, A., E. Lagarde, and L.R. Salmi. 2018. "Burden of Road Traffic Injuries Related to Delays in Implementing Safety Belt Laws in Low- and Lower-Middle-Income Countries." *Traffic Injury Prevention*. (Feb 28): 19 (sup1): S1-6.

Meerding, W. 2004. "Describing Health and Medical Costs, and the Economic Evaluation of Health Care: Applications in Injuries and Cervical Cancer." Rotterdam: Erasmus MC.

Moyer, J.D., M. Eshbaugh, and J. Rettig. 2017. "Cost Analysis of Global Road Traffic Death Prevention: Forecasts to 2050." *Development Policy Review* 35 (6): 745-57.

Myssayev, A., S. Meirmanov, T. Rakhypbekov, T. Bulegenov, and Y. Semenova. 2014. "The Characteristics of Road Traffic Fatalities in Kazakhstan's Semey Region, 2006-2010: A Descriptive Retrospective Study." *Iranian Journal of Public Health* 43 (6): 760-68.

Nevo, A., and A. M. Rosen. 2012. "Identification with Imperfect Instruments." *Review of Economics and Statistics* 94 (3): 659–71.

Oster, E. 2019. "Unobservable Selection and Coefficient Stability: Theory and Evidence." *Journal of Business & Economic Statistics* 37 (2): 187-204.

Otte, D., M. Jansch, and B. Wiese. 2013. "Injury Severity and Causation Factors of Motorcyclists in Traffic Accidents in Comparing Drivers of Motorcycles and All Kinds of Motorized Two-Wheelers." ***IMSC (International Motorcycle Safety Conference) Orlando, Florida, USA.***

Otte, D., M. Jansch, A. Morandi, C. Orsi, A. Banner, C.P. Bogerd, G. Tzamalouca, M. Papadakaki, J. Chliaoutakis, K. Parkkari, J. Dias, and T. Weber. 2015. *Final Report of Working Group 1: In-Depth Accident Observations and Injury Statistics*. COST Action TU1101 /, Brussels: HOPE.

Page, Y., S. Cuny, T. Hermitte, and M. Labrousse. 2012. "A Comprehensive Overview of the Frequency and the Severity of Injuries Sustained by Car Occupants and Subsequent Implications in Terms of Injury Prevention." *Annals of Advances in Automotive Medicine* 56: 165-174.

Perez, K., W. Weijermars, E. Amoros, R. Bauer, N. Bos, E. Dupont, A. Filtness, S. Houwing, H. Johannsen, B. Leskovsek, K. Machata, J. L. Martin, N. Nuyttens, M. Olabarria, L. Pascal, and W. Van den Berghe. 2016. "Practical Guidelines for the Registration and Monitoring of Serious Traffic Injuries: Deliverable 7.1 of the H2020 Project SafetyCube."

Plasencia, A., and E. Cirera. 2003. "Accidentes de Trafico: Un Problema de Salud a la Espera de una Respuesta Sanitaria." *Med Clin (Barc)* 120: 378-9 doi:10.1157/13044732.

Rocco, L., E. Fumagalli, A. Mirelman, and M. Suhrcke. 2021. "Mortality, Morbidity and Economic Growth." PLoS ONE 16 (5): e0251424

Rosén, E., H. Stigson, and U. Sander. 2011. "Literature Review of Pedestrian Fatality Risk as a Function of Car Impact Speed." *Accident Analysis and Prevention* 43 (1): 25-33.

Russell S. 1996. "Ability to Pay for Health Care: Concepts and Evidence." *Health Policy Planning* 11: 219–37.

Russell S. 2004. "The Economic Burden of Illness for Households in Developing Countries: A Review of Studies Focusing on Malaria, Tuberculosis, and Human Immunodeficiency Virus/ Acquired Immunodeficiency Syndrome." In Breman, J.G. et al. *The Intolerable Burden of Malaria II: What's New, What's Needed: Supplement to Volume 71(2) of the American Journal of Tropical Medicine and Hygiene.* Northbrook (IL): American Society of Tropical Medicine and Hygiene. Available at: https://www.ncbi.nlm.nih.gov/books/NBK3768/

Salam, R.A., A. Arshad, J.K. Das, M.N. Khan, W. Mahmood, S.B. Freedman, and Z.A. Bhutta. 2016. "Interventions to Prevent Unintentional Injuries Among Adolescents: A Systematic Review and Meta-Analysis." *Journal of Adolescent Health* 59 (4S): S76-S87. doi: 10.1016/j.jadohealth.2016.07.024. PMID: 27664598; PMCID: PMC5026686.

Segui-Gomez, M., MacKenzie, E. J. (2003). Measuring the public health impact of injuries. *Epidemiologic Reviews*, *25*, 3–19. https://doi.org/10.1093/epirev/mxg007

Selveindran, S., T. Tango, M. M. Khan, D.M. Simadibrata, P.J.A. Hutchinson, C. Brayne, C. Hill, F. Servadei, A.G. Kolias, A.M. Rubiano, A.J. Joannides, and H.K. Shabani. 2020. "Mapping Global Evidence on Strategies and Interventions in Neurotrauma and Road Traffic Collision Prevention: A Scoping Review." *Syst Rev*. 9 (1): 114. doi: 10.1186/s13643-020-01348-z. PMID: 32434551; PMCID: PMC7240915.

Sodikov, J. 2021. Road Mortality Rate Analysis in Central Asia, mimeo.

Staton, C., J. Vissoci, E. Gong, N. Toomey, R. Wafula, J. Abdelgadir, Y. Zhao, C. Liu, F. Pei, B. Zick, C.D. Ratliff, C. Rotich, N. Jadue, L. de Andrade, M. von Isenburg, M. Hocker. 2016. "Road Traffic Injury Prevention Initiatives: A Systematic Review and Metasummary of Effectiveness in Low- and Middle-Income Countries." PLoS One. 11(1):e0144971. doi: 10.1371/journal.pone.0144971. Erratum in: PLoS One. 2016;11(2):e0150150. Zhou, Yi [corrected to Zhao, Yi]. PMID: 26735918; PMCID: PMC4703343.

Staton, C., J. Vissoci, E. Gong, N. Toomey, R. Wafula, J. Amdelgadir, et al. 2015. "Road Traffic Injury Prevention Initiatives: A Systematic Review and Metasummary of Effectiveness in Low- and Middle-Income Countries." PloS ONE. 11 (1): e0144971.

Symons, J., E. Howard, K. Sweeny, M. Kumnick, and P. Sheehan. 2019. "Reduced Road Traffic Injuries for Young People: A Preliminary Investment Analysis." *Journal of Adolescent Health* (Jul 1) 65 (1): S34-43.

Tupetz, A., K. Friedman, D. Zhao, H. Liao, M.V. Isenburg, E.M. Keating, J.R. Vissoci, C.A. Staton. 2020. "Prevention of Childhood Unintentional Injuries in Low and Middle-Income Countries: A Systematic Review." PLoS ONE. (Dec 29) 15(12): e0243464.

Turner, B., S. Job, and S. Mitra. 2021. *Guide for Road Safety Interventions: Evidence of What Works and What Does Not Work*. Washington, DC: World Bank.

United Nations Road Safety Collaboration. 2010**.**

Vecino-Ortiz, AI, A. Jafri, and A.A. Hyder. 2018. "Effective Interventions for Unintentional Injuries: A Systematic Review and Mortality Impact Assessment Among the Poorest Billion." *The Lancet Global Health*. (May 1) 6 (5) :e523-34.

Viscusi, W.K. and Masterman, C.J. 2017. "Income Elasticities and Global Values of a Statistical Life." *Journal of Benefit Cost Analysis.* 8 (2): 226–50.

Watkins, D.A., N. Dabestani, R. Nugent, and C. Levin. 2017. "Interventions to Prevent Injuries and Reduce Environmental and Occupational Hazards: A Review of Economic Evaluations from Low and Middle-Income Countries." In: *Injury Prevention and Environmental Health. 3rd edition. Washington*, DC: The International Bank for Reconstruction and Development / The World Bank; Oct 27. Chapter 10.

White, K. L., T.F. Williams, and B.G. Greenberg. 1996. "The Ecology of Medical Care." *Bulletin of the New York Academy of Medicine 73 (1): 187–205.*

Wijnen, W. and H. Stipdonk. 2016. "Social Costs of Road Crashes: An International Analysis." *Accident Analysis and Prevention*. 94: 97–106.

Wijnen, W., W. Weijermars, W. Vanden Berghe, A. Schoeters, R. Bauer, L. Carnis, R. Elvik, A. Theofilatos, A. Filtness, S. Reed, C. Perez, and H. Martensen. 2017. "Crash Cost Estimates for European Countries, Deliverable 3.2 of the H2020 Project SafetyCube**."**

Wijnen, W., W. Weijermars, W. Vanden Berghe, A. Schoeters, R. Bauer, L. Carnis, R. Elvik, and H. Martensen. 2019. "An Analysis of Official Road Crash Cost Estimates in European Countries." *Safety Science* 113: 318–27.

Wijnen, W. 2021. "Socio-Economic Costs of Road Crashes in Middle-Income Countries: Applying a Hybrid Approach to Kazakhstan." *IATSS Research* 45 (3): 293-302.

Wisch M., M. Lerner, E. Vukovic, D. Hynd, A. Fiorentino, and A. Fornells. 2017. "Injury Patterns of Older Car Occupants, Older Pedestrians or Cyclists in Road Traffic Crashes with Passenger Cars in Europe: Results from SENIORS." International Research Council on Biomechanics of Injury. Conference. http://www.ircobi.org/wordpress/downloads/irc17/pdf-files/17.pdf

World Bank. 2017. *The High Toll of Traffic Injuries: Unacceptable and Preventable*. Washington, DC: World Bank.

World Bank. 2019. *Guide for Road Safety Opportunities and Challenges: Low- and Middle-Income Countries' Country Profiles.* Washington, DC: World Bank.

World Health Organization. Global Status Report on Road Safety. 2015. Geneva: World Health Organization.

World Health Organization. Global Status Report on Road Safety 2018. Geneva: World Health Organization. http://www.who.int/violence_injury_prevention/road_safety_status/2018/en/

WORLD BANK GROUP

www.worldbank.org