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Applying a hybrid approach to Kazakhstan

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Socio-economic costs of road crashes in middle-income countries: Applying a hybrid approach to Kazakhstan

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ABSTRACT

Information about road crash costs is a valuable input for road safety policy making and it is essential for conducting cost-benefit analysis of road safety interventions. This paper presents a methodology for assessing the socio-economic costs of road crashes as well as an estimate of the volume of these costs in Kazakhstan. Five costs components have been taken into account: medical costs, production loss, human costs, vehicle damage and administrative costs. A hybrid methodological approach has been used, which implies that three different types of methods have been applied to capture all costs: the human capital method (production loss), willingness to pay (human costs) and restitution costs method (other components). Input data were retrieved from existing databases from a variety of road safety stakeholders and other organizations. A household survey was conducted to collect additional information, including the willingness to pay for fatal crash risk reductions. Remaining data gaps have been bridged by using data from other countries. The socio-economic costs of road crashes in Kazakhstan are estimated at $6.8 billion in 2012, which corresponds to 3.3% of GDP. Human costs account for 81% of the total costs, vehicle damage for 11% and production loss for 6%. Administrative and medical costs are relatively very small cost components. More than half of the costs is related to injuries, while fatalities account for about a third of the total costs and property damage only accounts for approximately 10%.

1. Introduction

Besides having a huge emotional impact on the quality of life, road crashes also pose a very significant socio-economic burden [1,2]. Several costs result from road crashes, such as medical costs, loss of productive capacity, property damage, administrative costs and human costs (loss of quality of life and life years). Information on these costs can provide valuable input when a government must set its policy priorities and justify why it wishes to invest (more) in road safety [1]. Moreover, this information is needed for conducting cost-benefit analysis of road safety investments and other investments which affect road safety [3,4]. Cost-benefit analyses are commonly used to assess whether (road safety) investments are economically viable and to prioritize road safety investments on the basis of socio-economic profitability [5]. In a cost-benefit analysis, the costs per casualty or per crash are required in order to monetize road safety impacts on the basis of road crash cost savings. Furthermore, the socio-economic costs of road crashes are considered to be an important outcome indicator for road safety management [6,7]. This outcome indicator is frequently used in international reports on road safety performance in individual countries [8,9]. In addition, cost information can be used to compare the economic burden of road crashes to the economic burden of other policy issues such as congestion, environmental pollution or different types of accidents and injuries [10].

Recent international reviews show that assessments of road crash costs have been conducted in a large number of high-income countries. For example, the socio-economic costs of road crashes have been estimated in thirty-one European countries [3], most of which (thirty) are high-income countries. Moreover, high-income countries in other parts of the world, such as Australia, New Zealand, Singapore and the United States have also assessed these costs [1]. The reviews show that methodologies differ across countries, the most debated issue being whether or not a willingness to pay method should be applied. Nowadays, the majority of high-income countries has adopted the willingness to pay approach, in combination with other valuation methods.

In contrast, the number of road crash cost studies in middle-income countries is limited [1], although recent studies have been conducted in Egypt [11], Iran [12,13] and Sudan [14]. In these studies, either the human capital method [12,14] or the willingness-to pay method [11,13] has been applied. However, to capture all of the cost

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components a combination of methods is required as these methods are aimed at different cost components [3,15]. This paper presents an estimation of the socio-economic costs of road crashes in Kazakhstan using a hybrid methodological approach aimed at including all relevant socio-economic costs, both tangible and intangible, which has not been applied in middle-income countries before.

Kazakhstan is an upper middle-income country which has experienced rapid economic growth since the beginning of this century [16]. However, road safety performance is still quite poor in Kazakhstan. The World Health Organization [9] estimated the mortality rate (number of road fatalities per 100,000 people) to be 24.2 in 2013, which is above the average number for middle-income countries (18.4 in 2013) and much higher than the mortality rate in high-income countries (9.2). Just as is often the case in other low and middle-income countries, estimates of the costs of road crashes are not available in Kazakhstan, which presents an impediment for developing cost-effective road safety strategies and for spending the budgets made available efficiently.

The paper is structured as follows. The next section presents the hybrid methodology that has been applied to estimate the socio-economic costs of road crashes in Kazakhstan. Section 3 describes the various types of data sources that have been used to make the cost calculations. A more detailed discussion of the input data and methodology is provided in Section 4 (numbers of road casualties and crashes) and in Section 5 (method and data per cost element). The resulting costs are presented in Section 6, followed by a discussion (Section 7) and subsequently conclusions are drawn in Section 8.

2. Methodology

The costs of road crashes in Kazakhstan are viewed from a welfare economic perspective. According to welfare economic theory, which is the basis for cost-benefit analysis [4,17], the loss of welfare is related to usage of scarce resources such as human resources (labor) and capital as well as to intangible issues such as loss of quality of life. The net costs for society are calculated, regardless of whom bears the costs, which implies that financial transactions which do not represent a welfare loss are not included. Several examples are taxes and fines; on the one hand, these are revenues for government bodies, but on the other hand, they are expenditures for citizens and therefore, no net social cost occurs. Such money transfers do not represent a loss of welfare, and as a result, they are not included in the cost assessment.

Five types of welfare impacts, or socio-economic cost categories, are included following best practices in high-income countries [1,3] and international guidelines [15,18][1]:

- Medical costs: the costs of medical treatment and rehabilitation from injuries resulting from road crashes
- Production loss: loss of production and consumption due to the loss of human capacities
- Human costs: loss of quality of life and life years
- Property damage: damage to vehicles, roads, roadside objects and freight
- Administrative costs: costs of police and other emergency services, insurance and legal costs.

A distinction can be made between the costs related to injuries and the costs related to crashes. Medical costs, production loss and human costs are related to injuries, whereas property damage and administrative costs are related to crashes (Fig. 1).

Note that human costs are intangible costs, which are not reflected by market transactions and market prices. According to economic welfare theory, human costs should be included in road crash studies in order to reflect the full impact of road crashes on socio-economic welfare.

A hybrid methodological approach has been applied, based on best practices in high-income countries [1,3], international guidelines [15,18] and economic theory [4,19]. This implies that three different types of methods are applied so that all of the relevant socio-economic costs can be included [3,15]:

1. Restitution costs approach: this approach concentrates on the costs of resources that are needed to restore those who have suffered from road crashes, as well as their relatives and friends, to the previous situation as these costs would not have occured if they had not been involved in a road crash.
2. Human capital approach: in this approach the societal value of the loss of productive capacities of road casualties is measured.
3. Willingness-to-pay (WTP) approach: costs are estimated on the basis of the amount individuals are willing to pay for reducing risks.

The restitution costs approach is aimed at estimating medical costs, property damage and administrative costs [3,15]. This means that the direct costs of using resources (labor, equipment, etc.) for medical treatment, vehicle repair, emergency services, legal issues and insurance administration are estimated. In most cases, market prices are used to estimate these costs, assuming that market prices reflect the societal value of the resources.

The human capital approach is used to calculate production loss. In this approach, the loss of productive capacities related to road casualties is valued [19]. It is common international practice in road crash cost studies to calculate potential production loss [1,3], which means that the value of the goods or services that someone could have produced, if he or she was not killed or injured, is calculated, regardless of whether the person was actually (full-time) employed. Potential production loss accounts for the fact that the time loss suffered by the unemployed also has a socio-economic value. The unemployed may be productive in terms of household work, child care or voluntary work. A distinction can be made between gross production loss, which includes consumption loss, and net production loss which excludes consumption loss [10]. Gross production loss is measured by the (lost) value added or income that an employed person produces. Since part of this value added is used for paying wages, which in turn are used for consumption expenditure, consumption is implicitly included in gross production.

To estimate human costs, the WTP approach is applied as this is generally regarded as the most appropriate method for calculating human costs [3,15,21,22]. 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. The VSL does not reflect the value of individual lives, but statistical lives saved, since it is based on the willingness to pay for reducing the probability of dying in a road crash. The VSL includes human costs and consumption loss [10]. Consequently, human costs are calculated by deducting consumption loss from the VSL. This is also done to avoid double counting consumption loss, when the concept of gross production loss has been used.

A bottom-up approach is applied to calculate the size of each cost item: the costs per casualty or crash (unit cost) are determined and multiplied by the corresponding number of casualties or crashes in order to calculate the total costs per item. The only exception that is made is when calculating the costs of insurance: total costs are directly estimated and costs per casualty and crash are derived from the total costs (top-down).

All the costs have been estimated for the year 2012 and these have been expressed in the price level of 2012. The cost data from other years have been converted into the 2012 price level by using consumer price indexes as published by the World Bank [22] and the amounts expressed in local currency are converted into US dollars, using an exchange rate of 149.11 KZT per US$ [22].

[1] A category 'other costs' can be added, which includes congestion costs and costs of vehicle unavailability, among others [3]. These other costs are known to be relatively small [1] and for that reason they have not been included.

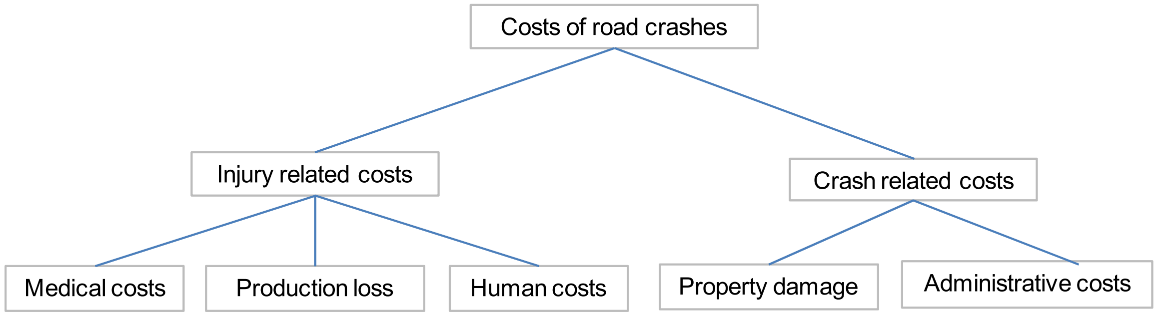

Fig. 1. Road crash cost components, based on BRS & TRL 2003 and Alfaro et al. 1994.

3. Data sources

Data on a variety of issues is needed for the assessment of road crash costs, including data on road casualties and crashes, medical treatment, labor market, damage to vehicles, police costs related to road crashes, insurance data and people's willingness to pay for crash risk reductions. To obtain the required data for the case of Kazakhstan, several types of data sources are utilized. Firstly, databases of several governmental institutions and other organizations are used, including the General Prosecutor's Office, Ministry of Interior, Administrative Police Committee, Agency of Statistics, Ministry of Economy and Budget Planning, Ministry of Health, Ministry of Labor and insurance companies.

Secondly, a household survey was conducted in March 2014 by Sange Research Centre to collect data that were not included in the databases of these organizations. Face-to-face interviews were held with a representative sample of the Kazakh population, stratified by region, age, gender and ethnicity. A combination of geographical, random route and quota sampling was applied. Quotas for region, age, sex, ethnicity were defined based on national demographic data. Regions were assigned to interviewers and each interviewer received fixed quotas for their region to interview respondents with certain age, sex and ethnicity characteristics. Households in each region were selected by dividing settlements on a map into 10 to 20 squares (depending on the size of the settlement). Each third square was selected for the survey and every third household was selected. If no respondent was available at the household, the interviewer went to the neighboring household.

Table 1
Number of respondents in the sample and total population by region.

Regions	Sample					Total population	
	Households	Shopping centers	Car repair garages	Total			
Akmola	44	4	9	57	4.2%	732,028	4.4%
Aktobe	51	5	10	67	4.9%	791,066	4.7%
Almaty region	98	10	20	127	9.3%	1,927,718	11.5%
Almaty city	116	12	23	151	11.1%	1,462,614	8.7%
Astana city	60	6	12	78	5.7%	760,541	4.5%
Atyrau	33	3	7	43	3.2%	549,091	3.3%
Batys	37	4	7	48	3.5%	615,068	3.7%
Jambyl	61	6	12	79	5.8%	1,062,843	6.3%
Karagandy	97	10	19	126	9.2%	1,360,312	8.1%
Kostanai	54	5	11	70	5.1%	879,699	5.2%
Kyzylorda	42	4	8	54	4.0%	719,795	4.3%
Mangistau	34	3	7	44	3.2%	556,754	3.3%
Ontustik	150	15	30	195	14.3%	2,650,187	15.8%
Pavlodar	51	5	10	66	4.8%	748,011	4.5%
Soltustik	33	3	7	43	3.2%	581,534	3.5%
Shygys	89	9	18	116	8.5%	1,394,164	8.3%
Total	1050	105	210	1365	100%	16,791,425	100%

The sample included 1050 respondents aged 18 years or older. In addition, 105 people were interviewed in shopping centers after the household survey was conducted, in order to make allowance for the low proportion of high-income households in the household survey. In addition, 210 people were interviewed in car repair garages to include more people who had been involved in a road crash, which were (only) used to estimate property damage by crash severity more accurately. Tables 1 and 2 present the number of respondents by region and by age, gender and ethnicity respectively, as well as comparisons with the total population.

The survey comprised three parts:

(1) The willingness to pay for improved road safety. This part includes questions on the respondent's risk understanding and on the willingness to pay for risk reductions in two scenarios (explained in more detail in Section 5).
(2) People's involvement in road crashes and the consequences of those crashes in terms of injuries and car damage. This section includes questions on how often respondents were involved in a crash, the severity of the injuries resulting from these crashes, the extent of car damage, police attendance at the crash location, car insurances and payments received from insurance companies.
(3) General question about the respondent, such as age, gender, income and education.

The full questionnaire is available as supplementary material.

Thirdly, in some cases a value transfer approach is used, which means that data or results of road crash cost studies in other countries are applied to the case of Kazakhstan. In particular, data from detailed road crash cost studies in high income countries that were included in a review conducted by Wijnen & Stipdonk [1] are used. The data from other countries particularly concern the number of road casualties and crashes, the duration of hospitalization and the length of absence from work. Obviously, it is uncertain to what extent these data reflect the actual situation in Kazakhstan. However, given the fact that these data are not available in Kazakhstan, nor in other low and middle-income countries, using data from high-income countries is considered to be the second-best option. Concerning unit costs, country-specific information for Kazakhstan was used for the calculation of each cost item. The Appendix contains an overview of the data from other countries that have been used in making the calculations.

4. Number of casualties and crashes

The number of road casualties and crashes (by severity) is a key input for road crash cost calculations. We distinguish between:

- Fatality: a person killed immediately or who has died within 30 days as a result of a road crash.
- Fatal crash: a crash resulting in at least one fatality.

Table 2
Percentual distribution of respondents in the sample and the general population over age groups, gender and ethnicities.

	Age group				Gender		Ethnicity		
	18–29	30–44	45–59	60+	men	women	Kazakh	Russian	Other
General population	31.2	30.1	24.2	14.5	48.3	51.7	65.5	21.5	13.0
Sample	31.3	30.2	24.2	14.4	48.3	51.7	64.9	22.0	13.1

- Serious injury: an injured person who has been treated in hospital requiring an overnight stay.
- Serious injury crash: a crash resulting in at least one serious injury (but no fatalities).
- Slight injury: a person who has been injured, but who has not been treated in hospital or who did not require an overnight stay.
- Slight injury crash: a crash resulting in at least one slight injury (but no fatalities or serious injuries).
- Property Damage Only (PDO) crash: a road crash causing damage to at least one vehicle, but no fatalities or injuries.

Additionally, the number of injuries resulting in a permanent disability and the number of slight injuries treated at the emergency department of hospitals are used to calculate production loss and hospital emergency treatment respectively.

The number of police-reported fatalities has been taken from the official statistics of the General Prosecutor's Office of Kazakhstan, which shows that there were 3022 road fatalities in Kazakhstan in 2012. The WHO [9] classifies Kazakhstan as a country with a good road fatality registration (at least 80% completeness) and therefore, this number is assumed to closely reflect the actual number of fatalities. The number of reported serious injuries was 25,461 in 2012 according to the statistics of the Agency of Statistics which have been based on hospital data. The degree of underreporting is not known. The ratio of the reported number of serious injuries to fatalities is 8.4:1 in Kazakhstan. This is at the lower end of the range of these ratios in other countries, where the ratio of the number serious injuries to fatalities (both corrected for underreporting) is between 6:1 and 26:1 (with the ratio in the UK as an outlier, 49:1, see Appendix). Therefore, we consider the number of serious injuries as reported by the Agency of Statistics as a plausible, but probably conservative, figure.

Statistics on the number of slight injuries and the number of crashes by severity are not available in Kazakhstan. We use the survey results to (roughly) estimate these numbers. Respondents ($N = 1155$) were asked if they, or their household members, had been involved in a road crash during the past three years and they were subsequently asked what the degree of their injury severity was in their two most recent crashes in that period. The survey revealed information on 319 injury crashes in which the respondents, or their household members, were involved. Table 3 shows the number of injuries that have resulted from these crashes by severity. The number of slight injuries reported by the respondents is 6.0 times higher than the number of serious injuries. This is consistent with the ratio found in other countries where this ratio ranges from 1:5 to 1:15 (see Appendix). We have applied a ratio of 1:6.0 to estimate the number of slight injuries at roughly 153,000.

The number of permanently-disabled casualties was determined by using data received from a large hospital. The data show that 3% of the road casualties treated in this hospital were 'extremely seriously' injured (20 out of the 670 casualties in 2012). We have applied this proportion to the number of serious injuries in Kazakhstan as a rough estimate, which is probably conservative because other casualties might also be classified as being lifelong disabled.

The number of casualties treated in the emergency department of hospitals has been estimated using survey results (Table 3). The survey shows that 26% of the slight injuries (69 out of 263) were treated in hospital (without requiring an overnight stay). Applying this proportion to the estimated number of slight injuries (180,000) results in 40,000 casualties treated in the emergency department of a hospital.

Information on the number of road crashes is not available in Kazakhstan. We have estimated the number of injury crashes (by severity) using the number of casualties in Kazakhstan and the ratio of the number of casualties to the number of crashes in other countries. Note that this ratio depends on country-specific crash characteristics, such as the occurrence of specific crash types (e.g. single vehicle crashes) and the vehicle occupancy rate. Since data regarding these characteristics are lacking in Kazakhstan, it is unknown which country reflects the situation in Kazakhstan most appropriately. Therefore, we have applied the unweighted average of the ratios in other countries to estimate the number of crashes in Kazakhstan. These average ratios are 1.08 for fatalities (1.08 fatality per fatal crash), 1.17 for serious injuries, and 1.32 for slight injuries (see Appendix). Applying these ratios to the number of casualties in Kazakhstan results in 2800 fatal crashes, 22,000 serious injury crashes and 137,000 slight injury crashes in Kazakhstan.

A (rough) estimate of the number of PDO crashes in Kazakhstan has been made using the information available from other countries, where the ratio of the number of PDO crashes to the number of serious injuries

Table 3
Number of injuries due to the two most recent injury crashes respondents were involved in in three years.

Injury severity	Number of injuries	Proportion
Slight, no hospital treatment required	194	61%
Slight, hospital treatment (but no overnight stay required in hospital)	69	22%
Serious	44	14%
Fatal injury	12	4%
Total	319	100%

Table 4
Number of road casualties and crashes used in the crash-cost calculations.

Severity category	Data source	Number
Number of fatalities	General Prosecutor's Office, Agency of Statistics (age distribution)	3022
Number of fatal crashes	Value transfer (ratio fatal crashes: fatalities in other countries)	2800
Number of serious (hospitalized) injuries	Agency of Statistics / Ministry of Health	25,461
Number of permanently-disabled injuries	Catastrophes' Medical Centre	784
Number of serious injury crashes	Value transfer (ratio serious injury crashes: serious injuries in other countries)	22,000
Number of slight injuries	Survey (ratio slight/serious injuries)	153,000
Number of casualties treated in the hospital's emergency department	Survey	40,000
Number of slight injury crashes	Value transfer (ratio slight injury crashes: slight injuries in other countries)	137,000
Number of PDO crashes	Value transfer (ratio PDO crashes/serious injuries in other countries)	560,000

ranges from 22:1 to 55:1 (and 165:1 in Austria as an outlier, see Appendix). We assume that the ratio of PDO crashes to the number of serious injuries is at least 22:1 in Kazakhstan, resulting in 560,000 PDO crashes as a rough and probably conservative estimate.

Table 4 summarizes the number of casualties and crashes in Kazakhstan.

5. Calculation method and data per cost component

5.1. Medical costs

The following medical cost items have been included:

- Transportation of casualties to hospital
- Treatment received in the emergency department of a hospital
- In-patient hospital treatment (requiring an overnight stay)
- Rehabilitation.

In addition, funeral costs have been included as a medical cost item, although these can also be classified as 'other costs' [3]. It is not uncommon, however, to include funeral costs along with the medical costs [18] and we have followed that same practice here. The costs of out-patient treatment (other than treatment in the emergency department) and non-hospital treatment (e.g. by a general practitioner) have not been included because data on these costs are not available in Kazakhstan. These costs are assumed to be relatively small compared to the costs of hospitalization.

Casualty transportation costs are calculated on the basis of the number of casualties transported to hospital by ambulance and the average costs per ambulance ride. Similarly, the costs of emergency treatment, in-patient hospital treatment and rehabilitation are calculated by using the number of casualties who have received a particular treatment and the average costs corresponding to each treatment (unit costs). Unit costs of in-patient hospital treatment and rehabilitation are calculated by using the average number of days that treatment has been received and the costs per day.

Data on unit costs, the average duration of hospital treatment and rehabilitation, as well as data relating to the number of ambulance trips for five regions in Kazakhstan (out of 12 regions) were provided by the Ministry of Health, which retrieved the data from hospitals. Average costs weighted by population size are used and the costs are adjusted to allow for regional price differences, using consumer price indices from the Agency of Statistics. The total number of ambulance rides is estimated by multiplying the ratio of ambulance rides to the number of reported hospitalized injuries in the five regions by the total number of reported hospitalized injuries in Kazakhstan. The proportion of fatalities treated in hospital, and the average duration of this treatment, are estimated by using results from studies in other countries (see Appendix).

Table 5
Input data for calculating medical costs.

Indicator	Source	Value
Yearly number of ambulance trips	Ministry of Health	53,000
Cost per ambulance trip	Ministry of Health	$30
Average duration of hospitalization per serious injury (days)	Ministry of Health	18
Average costs of in-patient hospital treatment per casualty per day	Ministry of Health	$70
Average costs of treatment at emergency department	Ministry of Health	$21
Average number of rehabilitation days per casualty	Ministry of Health	11
Average costs of rehabilitation per casualty per day	Ministry of Health	$60
Proportion fatalities treated in hospital	Other countries	27%
Average duration of hospitalization per hospitalized fatality (days)	Other countries	5
Cost per funeral	Total, 2012	$246
Social discount rate	Zhuang et al., 2007	8%

Funeral costs are calculated by taking the difference between the actual costs of a funeral and the future costs of a funeral if the person had not been killed in a road crash. The costs of a funeral are based on the results of a survey carried out by a news website [23]. The future costs are calculated as the present value of the costs of a funeral in a future year, which is determined using data from the Agency of Statistics on the age and gender of each fatality, and the life expectancy by age and gender. The future costs are discounted by using a social discount rate. The discount rate is set at 8% based on a review of social discount rates used in cost-benefit analyses, which shows that discount rates range from 3% to 7% in high-income countries and 8% to 12% in low and middle-income countries [24].

Table 5 summarizes the input values used to calculate medical costs.

5.2. Production loss

Production loss results from the fact that road casualties can no longer work, permanently (fatalities, severe injuries) or temporarily (injuries). Following international best practices, we have used the concept of gross potential production loss which, as discussed above, includes consumption loss. Gross production loss has been calculated by using the number of fatalities and serious injuries, the average length of time a person cannot work due to the crash and wages (as an indicator of the value of gross production per unit of time). For fatalities and permanently disabled, the duration of inability to work is the number of productive life years remaining. This period is calculated by using data from the Agency of Statistics on the age of those who have suffered serious injuries and fatalities, the age at which people enter the labor market (by gender and education level) and retirement age (by gender). The education level distribution of casualties is assumed to be equal to the distribution for the entire population. In regard to those who have been injured and who are not permanently disabled, the duration of absence from work is set at 30 days after leaving hospital based on a Russian road crash cost [25] and for slight injuries at 7 days (the average of other countries, see Appendix). Average gross yearly wages are used: $10,459 (men) and $7275 (women) (Source: Agency of Statistics). Future production has been discounted by using the 8% discount rate discussed above.

In addition, there are costs suffered by employers who must recruit and train new employees to (temporarily) replace injured employees. Data on these 'friction costs' were not available and for that reason these costs have not been included. These costs are known to be relatively very small [1].

5.3. Human costs

To estimate the value of a statistical life (VSL) in Kazakhstan, from which the human costs are derived, a stated preference survey was conducted among a representative sample of the Kazakh population aimed at determining the willingness to pay for a fatal crash risk reduction. Stated preference methods are very commonly used to derive the VSL in the context of road safety [26,27]. Particularly in Europe they are often preferred above revealed preference methods, which derive the value of risk reductions from actual behavior, such as purchasing behavior regarding safety provisions (e.g. airbags). One reason for this is that stated preference methods have a broader applicability as they are not dependent on information regarding actual (purchasing) behavior. Furthermore, consumers usually are not (fully) aware of the risk reduction resulting from their (purchasing) behavior, and stated preference methods allow to provide this information in order to help respondents in understanding the (small) risk reductions better [26]. On the other hand, stated preference methods are more prone to several types of bias related to using questionnaires, for example bias related to the hypothetical nature of the valuation questions [21,28].

A contingent valuation questionnaire design with two risk reduction scenarios was used. In the first scenario, respondents were asked to imagine that they travel once every month by car with a driver from their home town to a place at a distance of approximately 150 km. Two cars are available with each having different risks of being killed in a crash (20,100,000 and 10,100,000 respectively). The respondents were asked to state the maximum amount that they would be willing to pay per round trip, which means every month, for traveling in the safer car by choosing an amount from a payment card that showed various amounts ranging from 100 to 2500 KAZ (including the options 'less than 100 KAZ' and 'more than 2,500 KAZ'). In the second scenario, respondents were asked to imagine that they move to a city because of their work (or to another city if they already live in a city). They could choose between two cities consisting of 300,000 inhabitants that are identical except with respect to the level of road safety (3 versus 6 fatalities each month) and the costs of traveling to and from their work by bus. Respondents were asked what would be the maximum amount that they would be willing to pay extra per month for traveling to/from their work in the safer city compared to the other city, using the same payment cards. The highest risk level in both scenarios reflects the actual average risk level in Kazakhstan. Payment cards have been used here because respondents may have difficulties when answering willing to pay questions. Most people are not used to stating amounts of money directly, particularly in cases which they are not familiar with, such as road safety risks and small risks [21]. On the other hand, payment cards are prone to bias related to the range of amounts shown on the cards [28]. To minimize such 'range bias', a large number of amounts (20) was shown covering a wide range.

Before answering the valuation questions, small risks were explained to the respondents and the respondents' risk understanding was tested by using a grid boxes approach as applied by De Blaeij [28] and Bhattacharya et al. [29]. The respondents were shown a paper with 100,000 grid boxes, of which 20 boxes were shaded, and then the reverse side of the paper was shown where the grid boxes were not visible. The respondents were told that the probability of dying in a road crash in a year is equal to the probability of touching a shaded box if he/she puts a needle in the paper, and that this is a chance of 20 out of 100,000. Next, a similar paper was shown, but this time 40 out of 100,000 grid boxes were shaded. Two questions on the relative size of the risks were asked in order to test the respondents' understanding of small risks. Respondents who did not answer these questions correctly were excluded from the analysis.

In the first scenario (choice of car), respondents were willing to pay \$7.3 on average to lower their yearly risk of being killed in a crash from 20:100,000 to 10:100,000, which translates into a VSL of \$871,790. In the second scenario (choice of city) respondents were willing to pay \$6.0 on average to lower the monthly number of fatalities by 3, which results in a VSL of \$595,633. The lower WTP in the latter scenario might be explained by the fact that people are willing to pay more for the reduction of private risks (such as the risk of their car) than for public risks (for example, a safer road) [30].

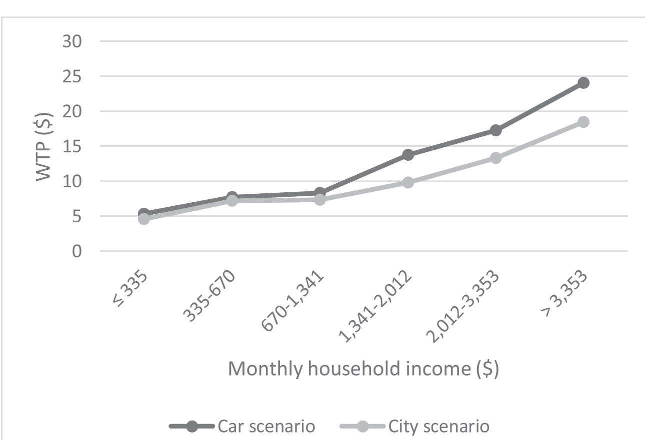

Fig. 2. Relationship between willingness to pay and income (\$).

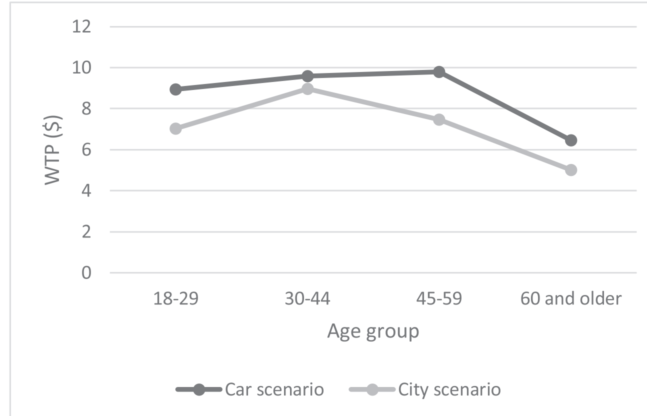

Fig. 3. Relationship between willingness to pay and age.

As expected, the WTP is found to increase with income in both scenarios (Fig. 2), which is consistent with findings in the literature on the relation between WTP for safety and income [31]. It reflects that people's budgets for safety expenditures increases with income. The WTP initially increases with age, and then it decreases from a certain age (inverted U-curve) in both scenarios (Fig. 3). This is consistent with several studies on the relationship between WTP and age, although positive, negative or no significant relations have been found in the literature as well [32].

The average VSL resulting from both scenarios (\$733,711) has been applied in order to calculate the human costs. Consumption loss has been deducted for the VSL in order to determine the human costs. Consumption loss per fatality, by age and gender, has been calculated as the sum of the yearly household consumption per capita in all of the remaining life years if a person would not have been killed in a road crash, using data on the age of fatalities, life expectancy by age and the discount rate.

Value transfer has been used to estimate the human costs related to injuries. Studies on the willingness to pay for reducing serious and slight injury risk, relative to the willingness to pay for reducing fatal risk, have been conducted in Belgium [33], Sweden [34] and the UK [35]. Table 6 summarizes the results of these studies (the value of preventing a serious injury as a proportion of the VSL). The value for slight injuries in Belgium refers to casualties who have been treated in hospital and it is therefore not applicable to slight injuries as defined in this study (no overnight stay required in hospital). Based on the results of these studies, we have applied a value of 13% of the VSL for serious injuries and 1% of the VSL for slight injuries to estimate the human costs related to injuries. These values correspond to the recommendations made regarding the valuation of road injuries in several European projects [36,37]. It is assumed that there is no consumption loss related to injuries, which implies that a correction for consumption loss (as was made with respect to fatalities) is not needed.

5.4. Property damage

Damage to vehicles is calculated using the number of crashes (by severity), the number of damaged vehicles per crash and the average

Table 6
WTP values per injury as a proportion of the VSL.

	Serious injuries	Slight injuries
UK	10%	0.9%
Sweden	16%	1.5%
Belgium	7–85%	1.6%

Table 7
: Average damage per car.

	Average damage per car	N
Fatal	404,692	7
Serious	114,373	38
Slight	82,122	223
PDO	73,970	271

damage per vehicle. The survey included questions on the number of vehicles involved in the most recent and next most recent crash the respondent (or a household member) was involved in and the damage done to his/her car. Table 7 shows the average damage per car by crash severity. The average number of cars involved in a crash (all severities) was 2.1 ($N = 256$).

Other property damage, such as damage to infrastructure, has not been included due to the lack of data. This damage is known to be very small compared to vehicle damage [1].

5.5. Administrative costs

Police costs have been calculated on the basis of the number of crashes by severity, the proportion of crashes the police attends, the police time spent per crash and the average wage police officers receive. The survey showed that the proportion of police attendance ranged from 43% for PDO crashes ($N = 162$) and 66% for slight injury crashes ($N = 172$) to 91% for serious injury crashes ($N = 32$). For fatal crashes 100% police attendance is assumed. Police time spent and the number of police officers attending a crash have been based on educated guesses using information provided by the Ministry of Interior and the General Prosecutor's Office (Table 8).

Costs of other emergency services (mainly fire department services) are estimated as a proportion of police costs. This proportion depends, among others, on crash severity and wage differences between the police and other emergency service personnel. Since there is no data available on this in Kazakhstan, we have applied the unweighted average proportion found in other countries (70% of police costs, see Appendix) to estimate the costs of other emergency services in Kazakhstan.

Administrative costs of vehicle insurances have been estimated by using data concerning the income that all insurance companies in Kazakhstan receive from vehicle insurance premiums ($230 million; Source: National Bank of Kazakhstan) and the ratio of administrative costs to premium income as provided by two large insurance companies in Kazakhstan (0.4:1, average weighted by market share of the companies). A correction was made for the fact that 1.6% of the cases are related to other damage causes than road crashes, such as theft and vandalism, according to data provided by one of the insurance companies. This resulted in an estimate of the administrative costs that were related to vehicle insurance of $82 million.

6. Results

Table 9 presents the total costs by cost component and severity level. The total costs of road crashes are estimated at $6.8 billion in 2012, which corresponds to 3.3% of the GDP (GDP was $208 billion in 2012 [22]). Human costs are estimated at $5.5 million, and thus account for a large proportion of total costs (81.1%). Property damage (damage to cars) is the most important other cost component, having a share of 11.3% in total costs, while production loss accounts for 5.9% of total costs. Administrative costs and medical costs are relatively small cost components, accounting for 1.3% and 0.4% of the total costs, respectively.

Table 8
Police time spent by severity of crash.

	Hours per crash	Number of policemen attending a crash	Total time spent (hours)
Fatal	4	6	24
Serious injury	3	4	12
Slight injury	2	3	6
PDO	1	2	2

Table 9
Cost of road crashes in Kazakhstan in 2012 (million US$).

		Fatalities	Serious injuries	Slight injuries	PDO	Total
Medical costs	*Transportation costs*	0.0	0.6	1.0	–	1.6
	Hospital costs, in-patient	0.3	19.0	0.0	–	19.3
	Hospital costs, out-patient	0.0	0.0	0.8	–	0.8
	Rehabilitation costs	0.0	1.6	0.0	–	1.6
	Funeral costs	5.3	0.0	0.0	–	5.3
	Total medical costs	5.6	21.1	1.8	–	28.5
Production loss		285.1	93.3	22.1	–	400.6
Human costs		2002.3	2414.7	1114.5	–	5531.5
Vehicle damage		16.0	35.2	134.1	583.5	768.8
Administrative costs	*Police*	0.3	1.0	1.9	2.0	5.2
	Other emergency services	0.2	0.7	1.4	1.4	3.7
	Insurance costs	0.3	2.5	13.5	65.4	81.8
	Total administrative costs	0.8	4.2	16.8	68.8	90.7
Total		2309.8	2568.6	1289.4	652.4	6820.1

More than half of the costs ($3.9 billion) is related to injuries. Fatalities account for about a third of the total costs, and PDO crashes for about 10%. The distribution of costs over severity categories differs between costs components: fatalities have a large share (71%) in production loss, whereas serious injuries account for a major part (74%) of the medical costs. PDO crashes have a share of 73% in both property damage and administrative costs.

Table 10 presents the costs per casualty and per PDO crash. The costs of a fatality are estimated at $764,000, the costs of a serious and slight injury at $101,000 and $8000, respectively and the costs of a PDO crash at $12,000.

7. Discussion

The calculations show that road crashes pose a very considerable socio-economic burden in Kazakhstan, corresponding to 3.3% of GDP. The size of this burden is within the range found in other countries: recent reviews found costs of road crashes ranging from 0.4% to 4.1% of the GDP in Europe [3] and from 0.5% to 6.0% of the GDP worldwide [1]. However, the calculated estimate for Kazakhstan can be regarded as a lower limit of the costs due to the fact that the analysis concentrated on the most important cost items and it did not include several other, although minor, cost items such as legal costs, damage to infrastructure and traffic congestion costs. Moreover, the costs are likely to be underestimated because the number of reported fatalities and serious injuries were

Table 10
Cost per casualty (1000 US$).

	Fatality	Serious injury	Slight injury	PDO crash
Medical costs	1.8	0.8	0.01	–
Production loss	94.4	3.7	0.1	–
Human costs	662.6	94.8	7.3	–
Property damage	5.3	1.4	0.9	10.4
Administrative costs	0.3	0.2	0.1	1.2
Total	764	101	8	12

used. The actual numbers of fatalities and serious injuries are expected to be higher due to underreporting. As a consequence the number of slight injuries and PDO crashes is also conservative, as these numbers were determined using likely, but also conservative, ratios of the number of slight injuries and PDO crashes respectively to the number of reported serious injuries.

The VSL in Kazakhstan ($ 0.73 million) is relatively low compared to VSLs in other countries according to academic literature. Milligan et al. [20] conducted a regression analysis using 308 VSL estimates. They developed value transfer functions for low and middle-income countries (LMIC), high-income countries (HIC) and all countries, that specify the relationship between the VSL and GDP per capita. If the value transfer functions for LMIC and for all countries are applied to Kazakhstan, using a GDP per capita of $12,387 in Kazakhstan [22], this results in a VSL of $3.7 million and $3.5 million, respectively.[2] However, the VSL in Kazakhstan is in line with an international rule of thumb developed within the International Road Assessment Programme [38]. Based on a regression analysis using VSLs from 22 countries, they recommend using a VSL of 70 times the GDP per capita in economic appraisal of road infrastructure investments. Hence, this would result in a VSL of $0.87 million in Kazakhstan. A likely explanation, which could account for the fact that this rule of thumb resulted in a lower VSL compared to the value transfer developed by Milligan et al. [20], is the fact that the regression analysis made by McMahon and Dahdah [38] used a VSL that was officially determined by the government (e.g. for use in cost-benefit analysis). Milligan et al., on the other hand, used a VSL that was determined in academic studies. The official VSLs are lower in many countries, as the policy makers or researchers who decide on the official national values may tend to choose more conservative values [3].

A striking result of our study is the high proportion of human costs in the total costs. However, a high proportion of human costs is in line with results found in other countries that use a WTP approach. The WTP approach is known to result in much higher values than other valuation methods, such as methods that use compensation payments which are paid by insurance companies to casualties or their relatives [1,2,39]. Recent international reviews of road crash costs estimates report that human costs account for 34% to 91% [3] and 46% to 68% [1] of total cost if a WTP-method is used.

It should be noted that ratio of the road crash costs to GDP (3.3%) should not be interpreted as the impact of crashes on GDP. GPD is only used to scale the cost and it is common international practice to present the costs of road crashes as a percentage of GDP [1,2,9]. However, the costs included intangible costs (human costs) which are not part of a country's GDP. Moreover, resources used for, for example, medical treatment and vehicle repair are regarded as costs in the welfare economic perspective. From the perspective of the GDP, however, medical treatment and vehicle repair contribute positively to GDP. Consequently, estimating the impact of road crashes on the GDP requires a different type of analysis [40].

A comprehensive estimation of road crash costs is quite demanding in terms of data requirements. Our analysis shows that a large variety of data is needed, including road safety, economic, demographic, medical, emergency service and insurance data. Although several types of data were not available in Kazakhstan, we were still able to make an estimate of all relevant cost elements. Data gaps were bridged by conducting a survey and using data from other countries (value transfer). Value transfer is commonly applied in road crash cost studies, although inevitably it brings along a certain level of uncertainty. Nevertheless, we consider value transfer as a preferable option when compared to fully omitting certain cost elements as this would result in underestimating the costs. This, in turn, would have bearing on the safety benefits if the results were to be applied in cost-benefit analysis. Still, it cannot be denied that data limitations pose a serious challenge for future road crash studies in other countries, particularly in low and middle-income countries. This applies to the data concerning the number of road casualties and crashes, and a proper system for accident reporting and addressing underreporting is essential. Moreover, collecting data through surveys is recommended for future road crash cost studies in other countries. This will improve the international knowledge base on road crash costs in low and middle-income countries, and allow more countries to use value transfer to supplement their national data.

The large socio-economic costs of road crashes in Kazakhstan indicate that significant benefits are to be expected from investments in road safety. Consequently, policy makers can use the results of this study for justifying (additional) government spending on prevention of road crashes and for setting priorities in the allocation of government budgets. Furthermore, this study provides essential input for cost-benefit analysis, which can help policy makers to spend (road safety) budgets efficiently. In a cost-benefit analysis the socio-economic crash cost savings are weighted against the cost of implementing road safety measures, in order to identify the most cost-beneficial investment options. Reviews of cost-benefit analyses of road safety measures show that the benefits of road safety investments are often (much) higher than the costs, due to high socio-economic costs of road crashes [51]. Moreover, there is evidence that the number of casualties can decrease dramatically if the most cost-beneficial measures are implemented [52]. This study indicates that similar results are likely to be expected in Kazakhstan, although further research on road safety programs and their costs and benefits would be needed to confirm that.

8. Conclusions

The socio-economic costs of road crashes in Kazakhstan are estimated at $6.8 billion, which corresponds to 3.3% of GDP. This estimate can be regarded as a lower limit of the costs, particularly given the fact that conservative estimates of the number of casualties and crashes have been used. This indicates that road crashes result in a huge and considerable socio-economic burden for the country of Kazakhstan. Given the relatively poor road safety performance in Kazakhstan when compared to other middle-income countries, combined with a relatively good economic performance, this was to be expected. The study shows that a comprehensive road crash cost assessment requires a wide variety of data from different types of data sources, which are often not readily available. Most data gaps can be bridged, however, by conducting a household survey or by using data from other countries. In the future, it would be recommended that similar studies in other middle-income countries be conducted, as this will help policy makers and other stakeholders to set policy priorities and to increase the awareness of road safety as a socio-economic problem, particularly in middle-income countries.

Declaration of Competing Interest

The author declares no conflicts of interest.

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[2] The value transfer function was modelled for the GDP per capita and VSL expressed in 2005 international dollars. We follow the calculation procedure described by Milligan et al. (2014) by first translating the GDP per capita in national currency 2012 into 2005 international dollars. Next, the VSL in international dollars 2005 resulting from the value transfer function has been transferred back to national currency 2012. The purchasing power parity in 2012 and GDP deflator indices for the US dollar in 2005 and 2012 from the World Bank [22] have been used for these conversions.

Appendix A

Country	Source	ratio number of serious injuries/ fatalities	ratio number of slight injuries/ serious injuries	ratio number of casualties/ number of crashes			number of fatalities treated in hospital	duration hospitalization fatalities (days)	duration absence from work (days)		ratio costs other emergency services/police costs
				fatal	serious injury	slight injury			serious injuries	slight injuries	
Australia	BITRE [41]	13	11	1.1	n.a.	n.a.	21%	6.2	32–260	5	0.89
Austria	Sedlacek et al. [42]	7	9	1.06	n.a.	n.a.	33%	5.3	133	13	0.71
Belgium	De Brabander & Vereeck [43]	6	7	n.a.	n.a.	n.a.	n.a.	n.a.	38	2	
Germany	Baum et al. [44]	14	5	1.08	1.15	1.35	n.a.	n.a.	47	9	n.a.
Netherlands	De Wit & Methorst [45]	26	15	n.a.	n.a.	n.a.	n.a.	n.a.	71	n.a.	0.53
New Zealand	Ministry of Transport [46,47]	12	9	1.07	1.18	1.29	n.a.	n.a.	12	3	n.a.
Switzerland	Sommer et al. [48]	18	11	n.a.	n.a.	n.a.	n.a.	n.a.	36–637	12	n.a.
UK	DfT [49]	49	8	n.a.	n.a.	n.a.	n.a.	4.6	64	10	n.a.
US	Blincoe et al. [50]	15	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iatssr.2020.12.006.

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