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Systematic Review

A Systematic Review of the Application of Road Safety Valuation Methods in Assessing the Economic Impact of Road Traffic Injuries

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Abstract: Road traffic injuries (RTIs) are increasingly claiming lives, particularly of those living in low- and middle-income countries (LMICs). To evaluate the economic consequences of RTIs, their financial impact on Gross Domestic Product (GDP) has been investigated by several studies using road safety valuation methods. This in turn has been used to quantify the resources required for investment on appropriate countermeasures to reduce the severity and frequency of RTIs. To investigate the frequency of use of road safety valuation methods in assessing the economic impact of road injuries, a robust systematic review was carried out with the aid of EPPI-reviewer software. The analysis of the evidence gathered showed that 55% of the included studies used the willingness-to-pay (WTP) method, 29% used human capital (HC), 11% used restitution cost and 5% used other methods. In high-income countries (HICs), the predominant method used was WTP, while HC was more common for middle-income countries. In addition, it was found that 49% of the studies in this field were conducted on HICs, whilst 4% focused on low-income countries (LICs). This indicates that there is a gap in the use of road safety valuation methods for LICs in the literature and therefore a need for further research.

Keywords: road traffic injuries; valuation method; systematic review; low-income countries

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1. Introduction

Road traffic injuries (RTIs) continue to be a burden on society and cause negative effects on a country's economy. RTIs can be fatal, serious or slight injuries and are defined as a traffic crash involving a moving vehicle and at least one casualty [1]. As reported by the most recent global status report on road safety, road traffic fatalities reached 1.35 million in the year of 2016 and have continued to rise in line with population growth [2]. It is noteworthy that for those aged 5–29 years, RTIs are the leading cause of death [2]. They particularly affect vulnerable road users, such as pedestrians, motorcyclists and cyclists, along with those in low- and middle-income countries (LMICs) as transport becomes increasingly motorised. The death rate in LMICs is nearly double that of high-income countries (HICs) [3]. Several studies [4–9] noted that RTIs, especially fatalities, cause a big financial burden on an economy. It is very unlikely that RTIs can be eliminated entirely, since people need to travel, which has a risk in itself; however, their occurrence and severity may be minimised [10] by investing more resources in road safety and choosing the safest means of travel [11]. HICs have successfully invested more resources into a safe transport system approach, which has contributed to a reduction in the number of mortalities [4]. The value of resources to invest could be determined by assessing the economic impact of road injuries on the country's Gross Domestic Product (GDP).

Assessment of the economic burden of RTIs may be evaluated using road safety valuation methods, which estimate the different cost components in monetary terms [12,13]. These methods can only be effectively used when the required data are available, which

could be a challenge in most LMICs [14,15]. As a result, it is important to investigate and understand the factors that affect the use of these valuation methods and their data requirements. Although COST 313 guidelines present a preferred valuation method [16], there is no clear standard to verify the most appropriate method for the economic analysis of RTIs [10]. When road safety valuation methods are integrated with traditional road investment appraisal models, they may alter the priority of projects based on cost effectiveness and risk reduction [17]. Therefore, there is a need to identify and examine the impact of these valuation methods and their frequency of use for specific country income groupings. This paper will aim to first examine the reason why certain methods are more commonly used in different economic groupings, and second, to identify gaps in the literature, particularly for low-income countries (LICs) where there appears to be very limited evidence (or data) about their use. To achieve this, a systematic literature review, which also seeks to establish the optimal valuation method for LICs, was carried out and is presented hereinafter.

1.1. Review Question

The initial step in conducting a systematic literature review is setting a well-defined review question. The main review question is as follows:

"What evidence supports the application of road safety valuation methods in assessing the economic impact of RTIs worldwide?"

This question sought to clarify the following questions:

1. What road safety valuation methods exist?
2. Have these methods been applied in LMICs and/or HICs?

1.2. Definition of Terms

RTIs are caused by road traffic crashes that occur on a communal road involving a casualty and any moving automobile, such as a car or motorcycle. RTIs involve fatalities, serious injuries or minor injuries. A casualty is any person that is injured or killed because of a road traffic crash. In this review, RTI severity levels were classified according to the Common Accident Data Set (CADaS) [1].

Income groupings were classified in four categories by the World Bank using the Atlas method. These categories include low-income, lower- and upper-middle-income and high-income countries [18].

Road safety valuation methods are used to assess the different cost components with their relative cost elements and items in monetary terms [12]. According to Anh et al. [19], Hills and Jones-Lee [20] and Jacobs [21], the different valuation methods include human capital (HC) or gross output, net output, life insurance, court-award, implicit public sector valuation and WTP or value of risk change. More recently, based on the COST 313 guidelines, the three main methods used for costing RTIs are restitution costs, HC and WTP [16].

2. Systematic Review Methods

A systematic review is a research method aiming to answer specific questions by gathering all accessible evidence that matches eligibility criteria which have been pre-specified in a review protocol. In this review, a well-structured protocol showing a step-by-step and clear procedure of the systematic review was developed in order to minimise bias, hence providing more reliable results. This process involves identifying all appropriate studies systematically in relation to eligibility criteria and carefully assessing their validity through different means, such as risk of bias assessment. The final cohort included studies which were subjected to a synthesis, where the findings were presented and compared systematically [22]. This review was not registered.

This systematic review was written using the guidelines provided by the Cochrane Handbook [22] and the Preferred Reporting Items for Systematic Reviews and Meta-analyses Protocols (PRISMA-P) 2020 checklist (refer to Supplementary Information, SI 1).

The research question was formulated in consideration of the PICOS (Population, Intervention, Comparison, Outcome and Study design) [22].

2.1. PICOS Inclusion and Exclusion Criteria

This review considered studies which assessed the economic impact of road injuries using a valuation method, such as WTP, HC or restitution cost, amongst others. The included studies were categorised according to the different income groupings as per the World Bank [18]. All ages, sex and ethnicities of the population were considered.

Studies that were published outside the range of 2001–2022 were excluded, along with journals that were published in languages other than English. Duplicate studies, those with no full-text files available and studies that did not apply a road safety valuation method for assessing the economic impact of RTIs were excluded.

2.2. Search Strategy

Keywords from the research questions were identified based on the main objective of the systematic review. These keywords were used to prepare a search strategy, keeping in mind the inclusion criteria. Synonyms or alternative words/phrases to the keywords were later identified and used as search terms. Having diverse search terms helped minimise the risk of omitting important literature. Based on the research question and inclusion criteria, the alternative phrases for the corresponding keywords and search terms with Boolean operators [23] can be found in SI 2.

2.3. Databases

After identifying the keywords, bibliographic databases were searched systematically for relevant literature. The main bibliographic databases included Engineering village, Web of Science, Scopus, EBSCOhost, ProQuest, Taylor & Francis, PubMed, Ovid and Cochrane. The main search engines were Google Scholar, Google and FindIt@bham, which is a searchable library catalogue for the University of Birmingham. A detailed list of these databases can be found in SI 3. Studies from Google Scholar were manually searched to find literature that was relevant for this review. The application of Boolean operators, wildcards and proximity operators such as "OR" and "AND" helped broaden or narrow the search [23].

2.4. Other Sources

Additional literature was manually searched using the websites of international organisations such as the World Health Organisation (WHO), the World Bank, the European Transport Safety Council (ETSC), the National Highway Traffic Safety Administration (NHTSA) and the Institute for Road Safety Research, the Netherlands (SWOV), amongst others. A detailed list of these sources can be found in SI 3.

2.5. Study Selection Process

A total of 3275 studies obtained from different databases were exported to the EPPI-reviewer software [24]. EPPI-reviewer is an online tool which assists in conducting the systematic review process by eliminating duplicate references, managing study records and analysing selected studies [22]. From these, 820 were duplicates, hence 2455 studies were subjected to the screening process. A total of 1908 studies were excluded as they were irrelevant following scrutiny of their titles and abstracts. The remaining 547 studies were assessed for eligibility, with 445 studies excluded as the full-text files could not be retrieved or they were irrelevant to this study following scrutiny of their full-text files. A total of 102 studies were considered for final review. A flow diagram summarising the study selection process, which involved four processes, namely, identification, screening, eligibility and included processes, is shown in Figure 1 [25].

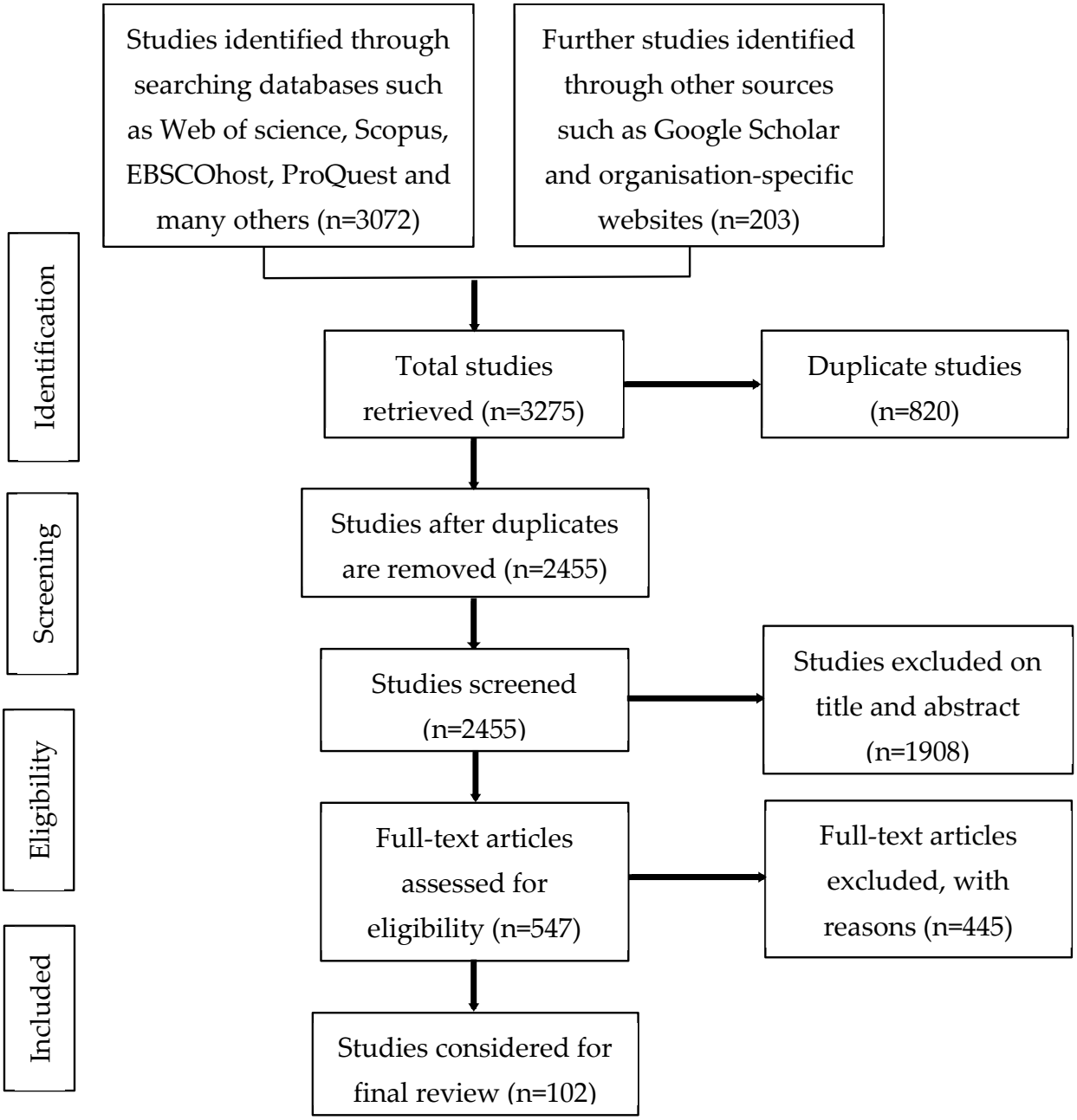

Figure 1. Screening process using a PRISMA flow diagram.

3. Results and Discussion

3.1. Valuation Methods

The three main road safety valuation methods used worldwide for assessing the economic burden of RTIs include restitution cost, human capital (HC) and willingness-to-pay (WTP) [12,16,26–28]. The main valuation methods used worldwide are elaborated below and shown in the flow chart in Figure 2.

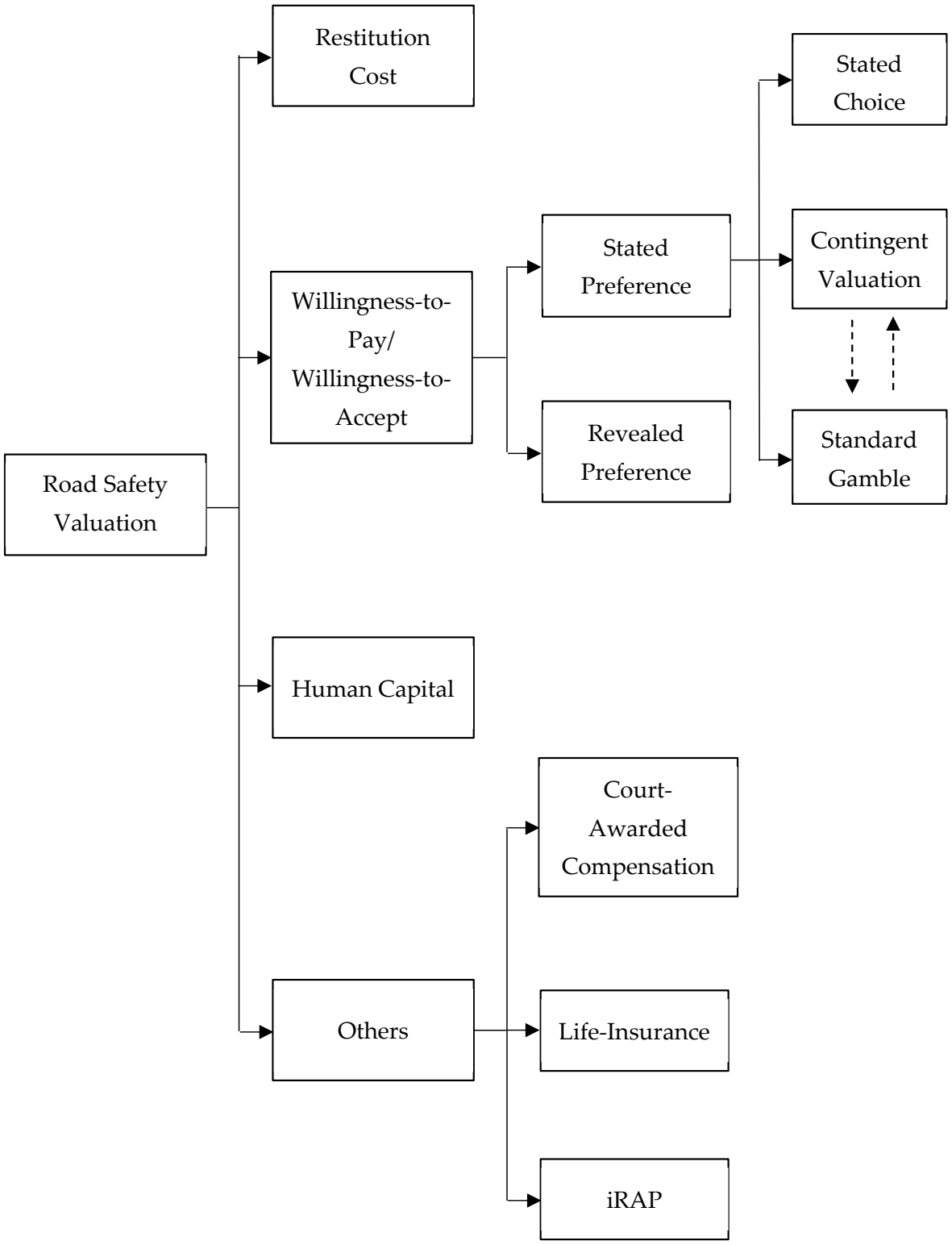

Figure 2. Flow chart showing road safety valuation methods.

3.1.1. The Restitution Cost Method

This method, also known as cost of restitution, involves direct costs incurred to restore the casualties, their family, relatives and friends to a position in which they would be had they not been involved in a road traffic crash causing an injury [12]. These direct costs can be valued using current market or representative prices. Examples of such costs include property damage (repairing damaged vehicles, road facilities or personal

property), medical costs (treatment for RTI victims or visiting the victim at the hospital), administrative costs (police, fire department, insurance and legal costs) and lost output or loss of productivity [12,29,30]. An example of the direct costs used for the restitution cost method is shown below.

$$\text{Direct costs} = \text{medical costs} + \text{property damage} + \text{administration costs} + \text{others (visiting victims in hospitals} + \text{friction costs} + \text{environmental costs} + \text{funeral costs} + \text{vehicle unavailability)} \quad (1)$$

3.1.2. The HC Method

This method, also known as ex post or gross output method, aims to calculate statistically the economic value of a person to society and therefore the loss of that value in the case of an injury or fatality [12,15,19]. The HC method is preferred for measuring lost output and a country's wealth maximisation [20]. Additionally, it is considered less complex compared to other methods, more consistent and easier to use due to its reliance on existing data [31]. However, it is not recommended for valuing human cost, which involves a value for the loss of quality of life, along with pain, grief and suffering [15,19,21,32].

The variables considered to compute lost output include GDP/GNP per capita, age of the victim, economic growth rate, discount rate, average retirement age, unemployment rate and total income per capita [12]. The lost output per fatality is computed as follows [19]:

$$\text{Lost output} = \sum_{t=0}^{n-1} \frac{Y(1+r)^{t+1}}{(1+d)^{t+1}} \quad (2)$$

where Y represents the average GDP per capita per year;

d represents the discount rate;
r represents the growth rate of the economy;
t represents the average number of years of lost production per fatality [19].

3.1.3. The WTP Method

This method, also known as an ex ante, measures how much an individual is willing to pay to reduce the likelihood and impact of a road injury. Additionally, the willingness-to-accept (WTA) method estimates how much a person is willing to accept for an increase in the risk of an injury occurring or premature death [12,19,21]. The WTP method most commonly uses survey questionnaires to obtain information from individuals about their trade-off for safety [20]. These questionnaires may, however, be too complicated and are based on hypothetical risk instead of real choice situations, which are considered difficult for the majority of the population in LMICs to comprehend [20,21]. Nevertheless, it is the preferred method for measuring human cost and the social well-being of individuals, since its values incorporate an estimate for pain, grief and suffering on society, while also producing a higher value of statistical life (VSL) than the HC method [15,28,33].

There are two main approaches under the WTP method, revealed preference (RP) and stated preference (SP). The SP method involves the use of survey questionnaires designed to estimate VSL, whereas the RP method is based on the actual purchasing behaviour of individuals, such as buying cars with different safety features [12,26,34]. This makes the RP method more challenging to implement since consumers may not be aware of the risk of their purchasing behaviour [34,35]. The contingent valuation (CV) [17,36,37] and the stated choice (SC) [38,39] methods are considered to be approaches under SP. The SC method of WTP was recommended by several studies because it relies on more real market situations [27,40,41]. Some studies recognise hedonic pricing [11,35] as a technique under the WTP method. Hedonic pricing involves considering various marketable factors that affect the pricing of goods and services; for example, the value of a safety device includes both its internal characteristics and external factors [42]. The standard gamble method is different but related to WTP, since it also involves the use of contingent valuation surveys to collect relevant data [43,44]. The standard gamble method estimates the risk an individual is willing to accept to avoid early death [42].

3.1.4. Other Methods

Estimating the VSL and Value of Statistical Injury (VSI) has commonly been conducted using the WTP method or iRAP methodology. The WTP method is, however, costly and more complex compared to the iRAP methodology [33]. Thus, iRAP has been preferred for estimating VSL, since it is already established on readily available data collected from countries which used either WTP or HC methods for their injury cost computations [45]. However, it was noted by Bhalla et al. [46] that the iRAP methodology overestimates the value of non-fatal injuries. Under this methodology, the VSL equates to 70 times the GDP per capita for the corresponding country, while the VSI equates to 25% of the VSL [33]. The VSL is the monetary value an individual is willing to pay to reduce the likelihood of an injury or early death occurring in the event of executing a certain activity [39], as expressed below:

$$\text{VSL} = \frac{\text{WTP for change in fatality risk}}{\text{change in the fatality risk}} \quad (3)$$

Connelly and Richard (2016) [7] suggest the use of court-awarded compensation as an alternative method to the SP and RP methods to measure the value of lost quality of life. This method relies on compensations awarded by the court to the surviving dependants of the victim to estimate the VSL [19,20].

The life insurance method considers the value that individuals place on their lives, which is also the cost of preventing the occurrence of a road crash [20]. It ignores the value of life, only valuing the earning capacity of an individual, whilst focusing on third party compensation. It is also common that the rich with no dependants may attach a higher value on their lives in order to survive [21].

3.2. Road Safety Valuation Methods Observed in Included Studies

A summary of the characteristics of the studies included in this review for in-depth analysis are shown in Table 1.

Table 1. A summary of characteristics of studies included in this review.

Method	Country	Data Collection	No. of Respondents	Target Population	Author(s)
WTP (CV)	Ethiopia	Questionnaires	750	1 city	Mekonnen et al. [47]
WTP (CV)	Sudan	Questionnaires	1400	2 cities	Mofadal et al. [48]
HC	Sudan	Existing data; questionnaires	1400	2 cities	Mofadal & Kanitpong [49]
Not specific	Uganda	Interviews	860	1 hospital	Mowafi et al. [14]
Restitution cost	Bangladesh	Interviews and existing data	369	16 districts	Mashreky et al. [50]
WTP (CV)	Bangladesh	Questionnaires	780	5 districts	Mahmud [51]
HC	Ghana	Existing data	N/A	2 accidents	Baidoo & Ketu [52]
HC and restitution cost	Ghana	Existing data and interviews	24	1 municipality	Kudebong et al. [53]
HC and restitution cost	Haiti	Existing data	N/A	1 hospital	Zuraik et al. [54]
WTP (SP)	India	Questionnaires and interviews	446	1 country	Balakrishnan & Karuppanagounder [55]
WTP (SP/CV)	India	Questionnaires	1200	1 country	Bhattacharya et al. [35]
System dynamics	India	Existing data, questionnaires and interviews	Not specific	N/A	Bora et al. [56]
HC	India	Existing data, questionnaires and interviews	95	1 city	Reddy et al. [57]

Table 1. *Cont.*

Method	Country	Data Collection	No. of Respondents	Target Population	Author(s)
HC (Gross Output)	Indonesia	Interviews and existing data	70	1 province	Sugiyanto [58]
HC	Indonesia	Interviews and existing data	100	1 province	Sugiyanto & Santi [59]
WTP (CV) and HC (Gross Output)	Indonesia	Questionnaires	50	1 country	Widyastuti and Mulley [60]
HC	Iran	Existing data	N/A	1 country	Ahadi & Razi-Ardakani [61]
WTP (CV, SP and RP)	Iran	Questionnaires	846	1 country	Ainy et al. [62]
WTP (CV, SP and RP)	Iran	Questionnaires	410	1 city	Ainy et al. [63]
WTP (CV, SP and RP)	Iran	Questionnaires	143	1 country	Ainy et al. [36]
WTP (CV, SP and RP)	Iran	Questionnaires	846	Not specific	Ainy et al. [64]
HC	Iran	Existing data	N/A	N/A	Hejazi et al. [65]
WTP (CV)	Iran	Questionnaires	590	1 city	Jarahi et al. [66]
HC and restitution cost	Iran	Existing data and interviews	N/A	1 hospital	Kavosi et al. [67]
HC	Iran	Existing data	N/A	2 hospitals	Rezaei et al. [68]
WTP (CV)	Myanmar	Questionnaires and interviews	1222	7 regions	Mon et al. [69]
WTP (CV)	Myanmar	Questionnaires	385	7 regions	Mon et al. [70]
HC and restitution cost	Nepal	Existing data	N/A	1 country	Banstola et al. [32]
HC (Gross Output)	Nepal	Existing data, interviews and questionnaires	100	1 zone	Sapkota et al. [71]
Restitution cost	Nigeria	Interviews	266	1 tertiary hospital	Urua et al. [72]
HC (Gross Output)	Philippines	Existing data	N/A	2 tertiary hospitals	De Leon et al. [73]
HC (Gross Output)	Vietnam	Existing data	N/A	1 country	Anh et al. [19]
WTP (CV)	Vietnam	Questionnaires	414	3 districts	Pham et al. [74]
WTP, HC and restitution cost	Azerbaijan	Questionnaires, interviews and existing data	200	1 country	World Bank [27]
HC	Belize	Existing data	N/A	1 hospital	Pérez-Núñez et al. [75]
WTP (CV)	China	Questionnaires	1050	1800 people	Liu & Zhao [76]
WTP (SP)	China	Questionnaires	1092	1 city	Zheng et al. [77]
Not specific	China	Existing data	N/A	1 country	Tan et al. [78]
WTP, HC and restitution cost	Colombia, Argentina, Mexico and Paraguay	Existing data	N/A	4 countries	Bhalla et al. [46]
WTP and HC	Jordan	Questionnaires, interviews and existing data	411	1 country	Ghadi et al. [79]
HC	Jordan	Existing data	N/A	1 country	Jadaan et al. [80]
WTP, HC and restitution cost	Kazakhstan	Questionnaires, interviews and existing data	1365	1 district	Wijnen [26]
WTP (CV)	Malaysia	Questionnaires	320	1 country	Mohd Fauzi et al. [81]
WTP (CV)	Malaysia	Questionnaires	855	1 country	Nor & Yusoff [82]
WTP (SP)	Malaysia	Questionnaires	3000	1 country	Yusof et al. [83]
WTP (SP)	Malaysia	Questionnaires	3000	1 country	Yusoff et al. [84]

Table 1. *Cont.*

Method	Country	Data Collection	No. of Respondents	Target Population	Author(s)
HC and restitution cost	Mexico	Questionnaires, interviews and existing data	297	4 medical facilities	Pérez-Núñez et al. [85]
HC	Serbia	Existing data	N/A	1 country	Antić et al. [86]
HC (Gross Output)	South Africa	Existing data	N/A	1 country	Olukoga & Harris [87]
WTP (CV)	Thailand	Questionnaires	1015	1 city	Chaturabong et al. [88]
WTP (CV)	Thailand	Questionnaires	1200	1 country	Puttawong & Chaturabong [89]
HC	Thailand	Existing data	N/A	1 country	Chantith et al. [8]
Personal Injury Recovery Cost (PIRC)	Australia	Existing data	N/A	1 country	Bambach & Mitchell [90]
HC	Australia	Existing data	N/A	8 states	Connelly & Supangan [7]
WTP (SC)	Australia	Questionnaires	385	1 country	Hensher et al. [39]
WTP (SC)	Australia	Questionnaires	312	1 country	Hensher et al. [91]
Personal Injury Recovery Cost (PIRC)	Australia	Existing data	N/A	1 country	Mitchell & Bambach [92]
WTP and HC (Gross Output)	Belgium	Existing data	Not specific	Not specific	De Brabander & Vereeck [6]
WTP (SP/SC)	Chile	Questionnaires	495	Not specific	Hojman, et al. [93]
WTP (SP)	Chile	Questionnaires	342	1 route	Rizzi & de Dios Ortúzar [94]
WTP (SP)	Chile	Questionnaires	320	1 country	Iragüen & de Dios Ortúzar [95]
WTP (SP)	Cyprus	Questionnaires and interviews	374	5 districts	Niroomand & Jenkins [96]
WTP (SP)	Cyprus	Questionnaires and interviews	374	5 districts	Niroomand & Jenkins [5]
WTP (SP)	Cyprus	Questionnaires and interviews	378	5 districts	Niroomand & Jenkins [97]
Restitution cost	Denmark	Existing data	N/A	1 country	Kruse [98]
WTP (SP/CV)	France	Questionnaires and interviews	2226	2 areas	Haddak [99]
WTP (CV)	France	Questionnaires	194	1 country	Haddak et al. [37]
WTP (SP/CV)	France	Questionnaires	2226	1 area	Haddak [100]
Restitution cost	Greece, Germany and Italy	Questionnaires and interviews	93	3 countries	Papadakaki et al. [101]
Standard gamble	Japan	Questionnaires and interviews	641	1 country	Koyama & Takeuchi [43]
Restitution cost	Netherlands	Questionnaires and interviews	1024	1 country	van der Vlegel et al. [102]
WTP (SP)	Norway	Questionnaires	2963	1 country	Flügel et al. [103]
WTP (SP)	Poland	Questionnaires and interviews	1085	1 country	Jaździk-Osmólska [104]
HC	Portugal	Existing data	N/A	1 country	Donário et al. [10]
HC	Romania	Existing data	N/A	1 country	Drosu & Cofaru [9]
WTP	Saudi Arabia	Questionnaires	148	1 city	Mohamed [105]
HC	Singapore	Existing data	N/A	1 country	Chin et al. [106]
HC	Singapore	Existing data	N/A	1 country	Chin [107]
HC (Gross Output)	Singapore	Existing data	N/A	1 country	Chin [108]

Table 1. *Cont.*

Method	Country	Data Collection	No. of Respondents	Target Population	Author(s)
WTP (SP/CV)	Singapore	Questionnaires and interviews	1500	1 country	Le et al. [109]
WTP (SC)	Spain	Questionnaires and interviews	477	1 city	González et al. [38]
WTP (CV)	Spain	Questionnaires and interviews	2020	1 country	Sánchez-Martínez et al. [44]
WTP (RP)	Sweden	Existing data	N/A	1 country	Andersson [11]
WTP (CV)	Sweden	Questionnaires	977	1 country	Andersson [110]
WTP (CV)	Sweden	Questionnaires	1950	1 city	Andersson & Lindberg [111]
WTP (SP/CV)	Sweden	Questionnaires	871	1 country	Andersson et al. [112]
WTP	Sweden	Questionnaires	977	1 country	Andersson [113]
WTP (SP/CV)	Sweden	Questionnaires	920	1 country	Andersson et al. [114]
WTP (SP/CV)	Sweden	Questionnaires	1022	1 country	Andersson Järnberg et al. [115]
WTP (CV)	Sweden	Questionnaires	873	1 city	Hultkrantz et al. [116]
WTP (SP/CV)	Sweden	Questionnaires	940	1 city	Krüger & Svensson [117]
WTP (CV)	Sweden	Questionnaires	675	1 city	Persson et al. [118]
WTP (SP/CV)	Sweden	Questionnaires	1148	2 cities	Svensson [41]
WTP (SP/CV)	Sweden	Questionnaires	1500	1 city	Svensson [119]
WTP (SP)	Sweden	Questionnaires	1500	1 city	Svensson & Johansson [120]
WTP (SP)	Taiwan	Questionnaires and existing data	4089	1 country	Jou & Chen [121]
WTP (SP/CV)	Taiwan	Questionnaires	2122	1 country	Jou & Chen [122]
WTP	UK	AIS and national accident statistics	300	1 country	Morris et al. [123]
WTP	UK	Existing data	N/A	1 city	Campbell et al. [4]
WTP (CV)	USA	Questionnaires	723	1 city	Bishai et al. [124]
HC	USA	Existing data	N/A	1 country	Blincoe et al. [125]
Not specific	USA	Existing data	N/A	1 state	Dicker et al. [126]

From the results, it was observed that the main road safety valuation methods applied were WTP, HC and restitution cost, as shown in Figure 3. These methods could be subdivided further, especially WTP, where 48 studies applied the stated preference/contingent valuation (SP/CV) approach, 1 study applied the revealed preference (RP) approach, 3 studies applied the stated choice (SC) approach and 11 studies did not specify what category of WTP method they had applied. In total, 63 studies applied WTP, 34 studies applied HC, 13 studies applied restitution cost and 6 studies applied other methods for road safety valuation. In reference to the other methods that were applied, two studies used the Personal Injury Recovery Cost (PIRC) approach, one study applied System dynamics and three studies did not specify what method was applied. Of the included studies, 11 applied more than one method in a single publication; for example, the application of WTP, HC and/or restitution cost. Although the WTP and HC methods are often applied as alternatives, they could be considered complimentary since they consider different cost components. For example, WTP for human cost and HC for lost output [127].

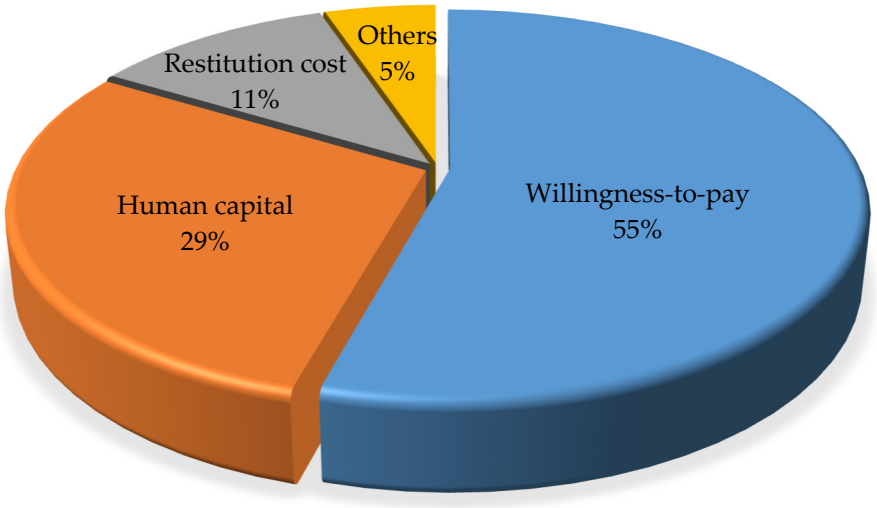

Figure 3. A breakdown of road safety valuation methods used for road injury costing.

WTP was used most frequently for high-income countries, while for low- and middle-income countries, HC was more commonly used. This aligns with recommendations made by some researchers [15,21] indicating that HC is the most suitable method for low- and middle-income countries. Some studies did not explicitly state the use of the restitution cost method. However, according to our definition discussed earlier, direct costs are usually computed using this method. Therefore, we considered studies that included direct costs to have used the restitution cost method. For example, Mashreky et al. [50], Zuraik et al. [54], Urua et al. [72], Kruse [98] and Papadakaki et al. [101].

Several researchers argue that the WTP method was the preferred method because it factors human cost of pain, grief and suffering, while generally producing a higher VSL than the HC method [12,15,33].

3.3. Data Gathering

The accuracy of any model depends on the quality and quantity of the data used. It is worth noting that road safety valuation studies collected data in several ways, with survey questionnaires, interviews and existing data dominating. Survey questionnaires were the most frequently used data collection tool for WTP studies, with over 70% of data collected using them for our included studies. Some studies, however, obtained information from government databases, without carrying out their own surveys [4,123], while WTP/RP studies used existing data from consumer purchasing behaviour to value road safety [11].

Interviews were mostly carried out to obtain direct costs incurred by casualties and their care takers, without forgetting crash-related costs. Data from such interviews were mainly used to compute restitution costs, along with questionnaires. It should be noted that only 13 studies considered restitution cost as a method, compared to 63 for WTP, so there is more uncertainty in the data. Data from interviews were also used to compute lost output due to road crashes. Nevertheless, existing data were predominantly collected to compute lost output, such as employment details, age, life expectancy and country's discount rate for use in the HC method. The different data sources used by the included studies for road safety valuations are shown in Figure 4.

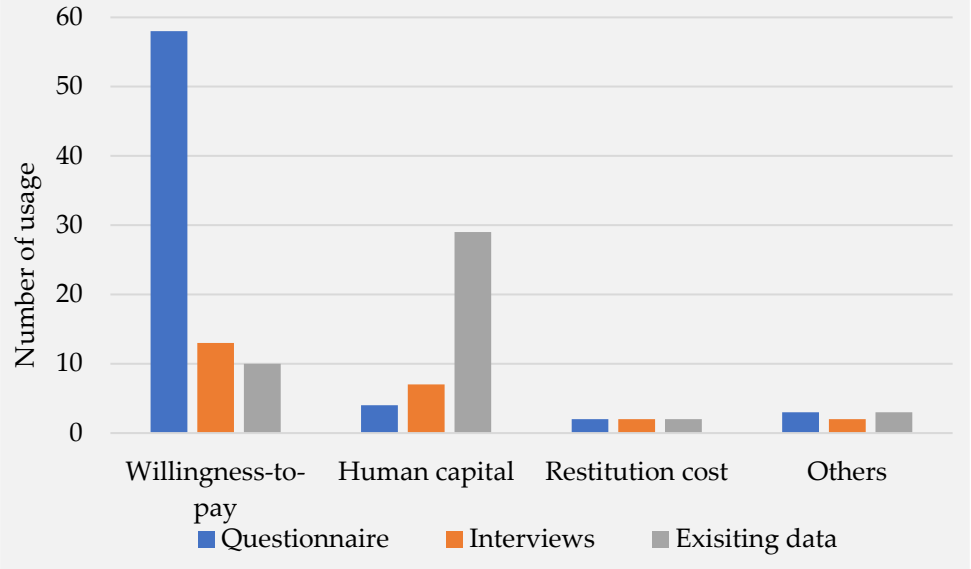

Figure 4. Categories of data sources and frequency of use per road safety valuation method.

3.4. Application of Road Safety Valuation Methods Worldwide

Initially, countries were categorised into four income groupings, LICs, lower-middle-income countries, upper-middle-income countries and HICs, according to the World Bank [18]. Numerous studies categorise economies into developing and developed, which in many cases may not clearly represent LICs. To understand the situation in all countries, it is important to categorise them into their appropriate income groupings, as it is very likely that there may be significant differences between varying economies such as LICs and upper-middle-income countries. Consequently, factors affecting growth (for example risk aversion) in LICs could differ from those affecting growth in upper-middle-income countries and HICs, as shown in a study carried out in Chile [40].

From the results of this study, it may be pointed out that although road safety valuations have been applied worldwide, more have been conducted in HICs than any other economy. Nearly half (49%) of the included studies are from HICs, which accounted for 50 studies, with 19 studies (19%) from upper-middle-income countries, 29 studies from lower-middle-income countries (28%) and 4 studies (4%) from LICs, as shown in Figure 5. It is noteworthy that some countries have moved into different income groupings from when the studies were originally carried out. Subsequently, the countries' current income groupings were considered at the time of this review.

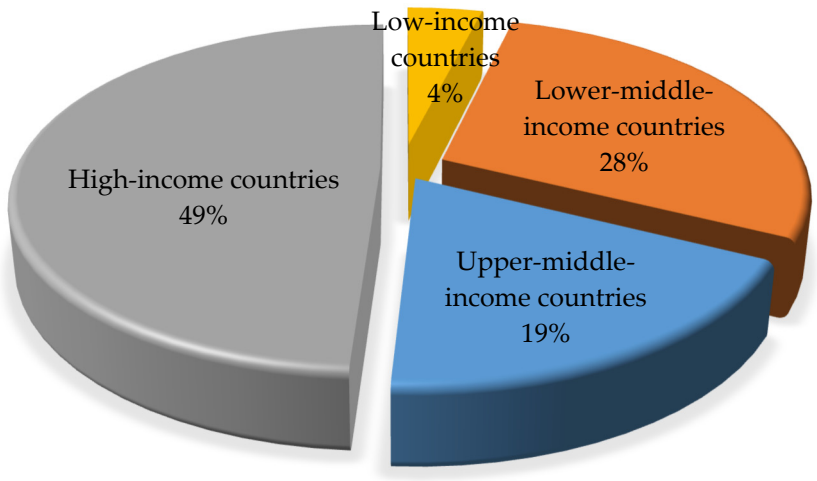

Figure 5. The breakdown of valuation method usage characterised by income group.

Figure 6 shows the number of countries by income groups versus the number of countries represented by the studies included in this review. It seems that LICs are under-represented, which may be due to an insufficient availability of data required for comprehensive analysis [14,32,45]. Several LMICs may rely on the rule-of-thumb method for economic evaluation of road crashes [27,33,45]. In many HICs, governments have published road crash data which have been used in projects such as SafetyCube to assess the impacts on stakeholders [28].

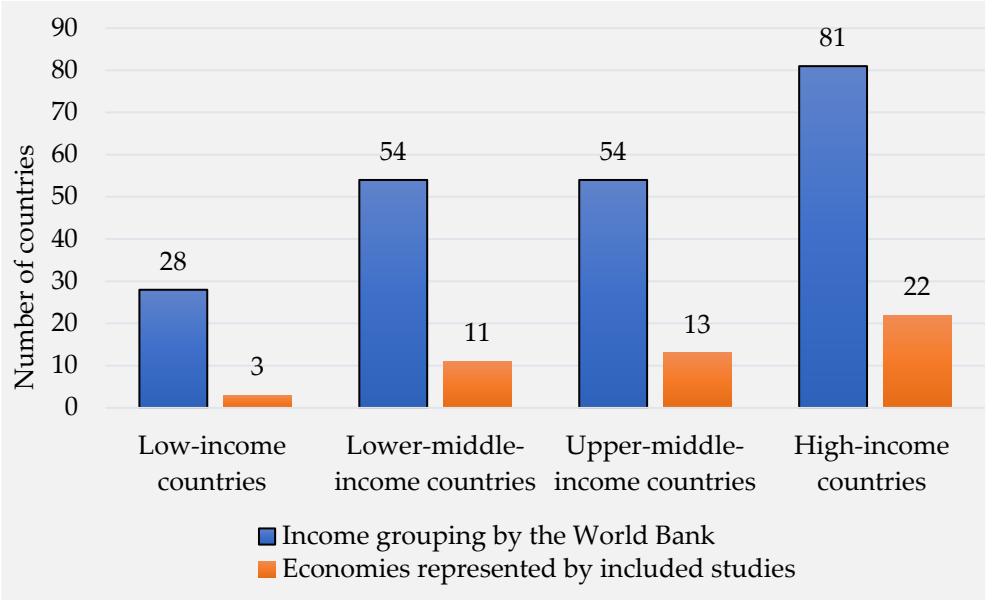

Figure 6. Number of countries by income grouping versus the number of countries represented by included studies.

Overall, HICs were the most represented, with 27% of these countries (22 countries) having at least one study, followed by 24% of upper-middle-income countries (13 countries), then 20% of lower-middle-income countries (11 countries) and finally 11% (3 countries) of LICs. This indicates that there is a gap in LICs as limited research has been conducted in this subject area.

The application of the different road safety valuation methods for road injury costing by income group is represented by Figure 7. From this, it may be observed that the WTP method was most widely used for HICs and least used in LICs. This method was also used in middle-income countries, although the results show that the HC method was more frequently used in lower- than upper-middle-income countries.

In addition to the WTP method, the HC method was also used for LICs, though insufficient literature was available. Overall, more studies were carried out in HICs than all the other income groupings. There were additional methods other than the WTP, HC and restitution cost that were used by some studies, as shown in Figure 7. It is very difficult to draw conclusions based on these findings since the studies are few and hence less representative of their respective country income groupings.

It was very difficult to conclude what method was most used in LICs, as only four studies were included in this review. Of the four studies, one study used the HC method, two studies used the WTP method and one did not specify what method was used, since it did not compute the total injury cost due to scarcity of relevant data [14]. However, a number of researchers [15,19,21,33] suggested that the HC method is more applicable for low- and middle-income countries, since it follows a less lengthy and less complex procedure as compared to the WTP method. Additionally, the iRAP methodology was recommended to be used to cover the unavailability of relevant data, as it is established on existing data from countries which used either WTP or HC methods for road safety

valuation. Therefore, it is likely that most LICs use this method to estimate VSL, since several researchers [14,32,45] mention the challenge of unavailability of required data for road safety valuation. The rate of underreporting and misclassification of injuries, especially by the police, in LMICs is very high, affecting the road safety valuation studies [10,32,56]. It was noted that most of the countries did not update their injury cost annually, yet Chin et al. [106] mention that it is important to update the injury cost annually, since the cost figure changes with the number of injuries, which vary with time.

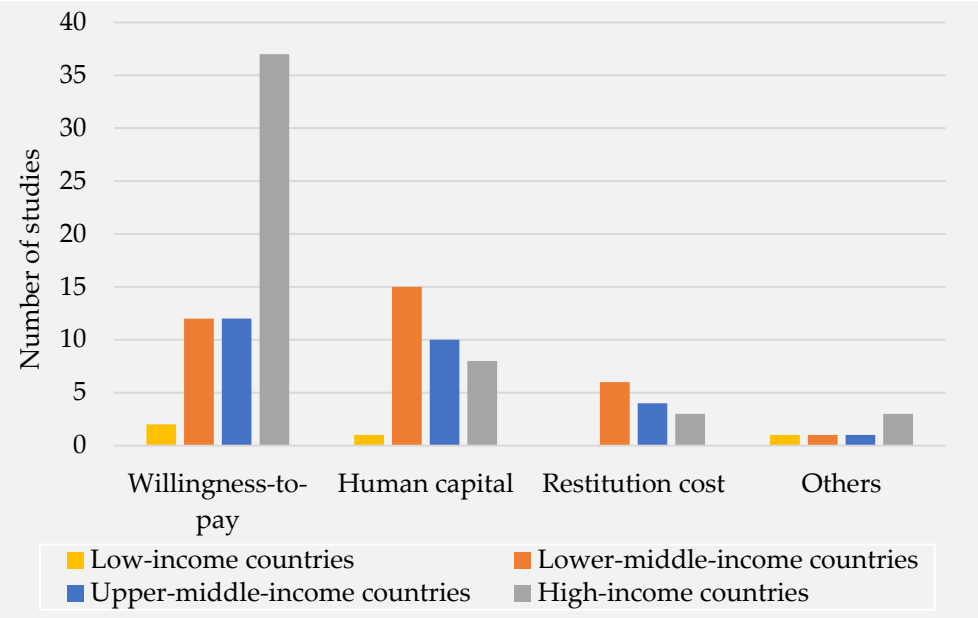

Figure 7. Valuation method applicability per income grouping.

4. Recommendation

The lack of publications for LICs in this area, combined with the alarming road safety records, highlight the research gaps, while leaving scope for further investigation. Valuation of the economic impact of RTIs in LICs would support the justification of road safety investments, which in turn could promote economic growth and help to save lives. More broadly, research is needed to cover this gap and allow for more reliable road safety valuations. This may focus on the appropriateness of the methods in relation to their data requirements, availability and management.

5. Conclusions

The aim of this review was to investigate the existing evidence supporting the use of road safety valuation methods for assessing the economic impact of road injuries in LMICs and/or HICs by means of a systematic review. This is the first systematic review that has been carried out to clarify the current state of knowledge with regard to the desirability of road safety valuation methods and their data collection, especially for low-income countries. The following conclusions may be made based on the results of this review:

The most frequently used road safety valuation method was WTP (55%), followed by HC (29%) and thirdly, restitution cost (11%).

The primary data source used for WTP studies was questionnaires, while for HC, existing data were predominantly employed. Studies that applied the restitution cost method used a mix of questionnaires, interviews and existing data.

In HICs, the most frequently used method for assessing the economic impact of RTIs was WTP, while HC was slightly more common in lower-middle-income countries. It was difficult to establish what road safety valuation method was predominantly used in LICs due to insufficient data retrieved for this review.

In terms of method usage as characterised by income groupings, HICs had the highest representation in the literature at 49%, followed by lower-middle-income countries (28%), upper-middle-income countries (19%) and LICs (4%).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/futuretransp3040069/s1, SI 1: PRISMA 2020 Checklist; SI 2: Alternative phrases to the keywords used in this review; SI 3: Databases searched in this review.

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