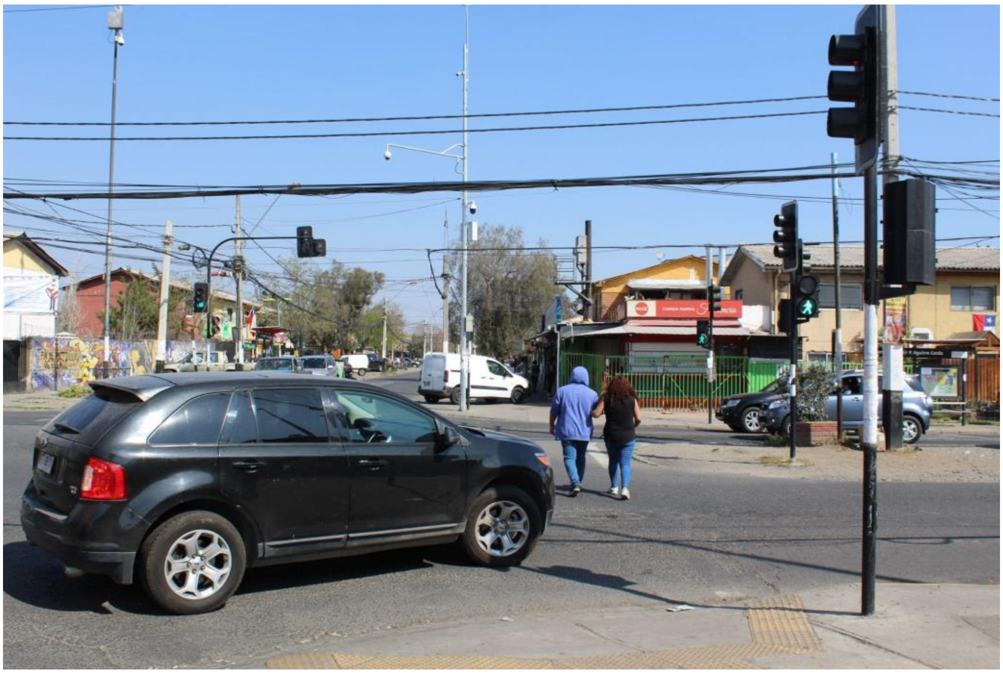
Leading Pedestrian Interval Implementation in Chile



Pedestrians and car driver interacting in an intersection with traffic light in Chile,
Photo: Maximiliano Zúñiga, MEL (Movimiento contra el Exceso de velocidad Letal)

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Transport Policy and Evaluation

Group B

Axel Rimbaud
Pietro Podesta’
Sachin Mishra
Marc Jacob

Foreword

This report makes use of numerical values to describe, analyse and evaluate road safety and related policies. It is sometimes easy to forget that behind those numbers, there are real people who died or got injured from road crashes. This is the case for example of Pilar Basterrica Bañados who, in 1999, was hit by a turning truck while she was crossing the street with a green pedestrian light. As a consequence of the impact, she lost half of her foot. Today she works for the Chilean Road Safety Commission (CONASET) to improve road safety. This paper is dedicated to Pilar, all the road crash victims and their families and loved ones.

Abstract

Society as a whole suffers significant losses as a result of road traffic injuries. Every year, approximately 1.3 million people's lives are cut short as a result of traffic crashes. This is the main cause of death for people aged between 5 and 29. Non-fatal injuries affect between 20 and 50 million more people worldwide. The situation in Chile has not improved over the years, with 2021 being the year with more road crash fatalities in the last 13 years. To improve people's safety in the chilean streets, the NGO "Movimiento contra el Exceso de velocidad Letal" (MEL) has sent a letter to the Minister of Transports asking to evaluate the implementation of a Leading Pedestrian Interval (LPI) pilot project in Chile. The LPI is a low-cost adjustment to signal timing that aims to increase pedestrian safety at signalised intersections. This study consists of an evaluation of its possible impact in Chile through a Cost Benefit Analysis (CBA) based on the fatalities and injuries historical data gathered by the Chilean Police and reviewed by the commission for road safety (CONASET). The results show that the implementation of a LPI pilot project for 10 intersections would be beneficial for Chile with a Benefit Cost Ratio of 4.7. To further guide decision makers, a decision-support tool is presented in the form of a Multi Criteria Decision Analysis (MCDA), which includes evaluations that are either non-quantifiable in monetary value or for which additional data is needed. This was developed with the intention of helping authorities with the selection of the most suitable intersections among the ones filtered by the CBA.

1. Introduction

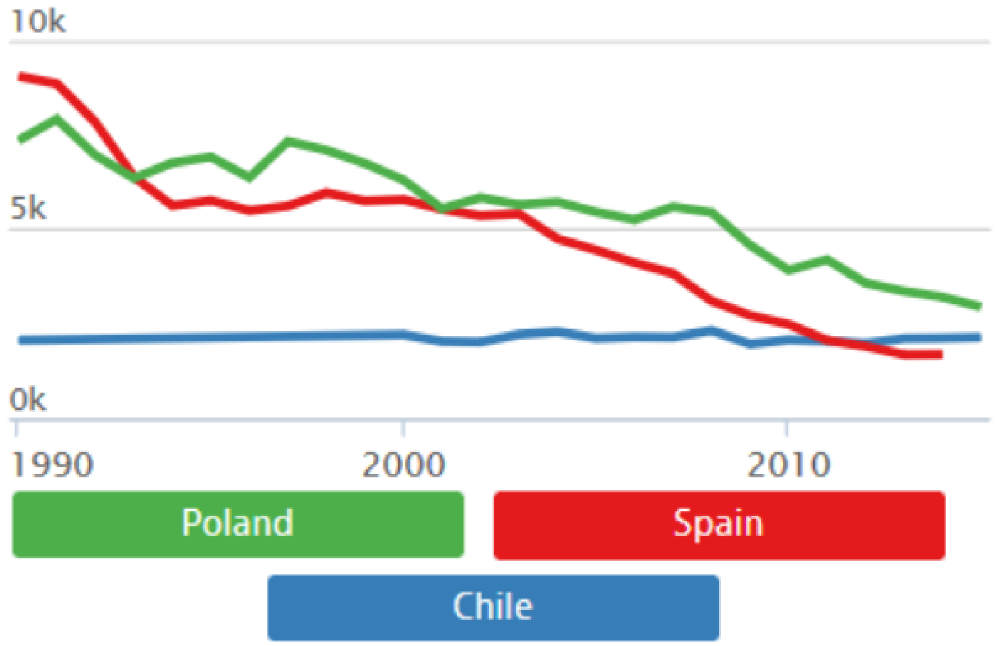
According to the World Health Organisation (WHO)'s Global status report on road safety 2018, "*the number of annual road traffic deaths has reached 1.35 million. Road traffic injuries are now the leading killer of people aged 5-29 years. The burden is disproportionately borne by pedestrians, cyclists and motorcyclists, in particular those living in developing countries*."[1] It is also estimated that between 20 and 50 million people are injured on the roads each year globally.

This is why the United Nations General Assembly (UNGA) will hold a high-level meeting on improving global road safety in July 2022. The UN's 2030 Agenda contains two targets specifically addressing road safety: Sustainable Development Goals (SDG) target 3.6, to halve the number of global deaths and injuries from road traffic crashes (on which the UNGA passed a resolution in August 2020); and SDG target 11.2, to improve road safety in the provision of access to transport systems and expanding public transport.[2]

In 2019, it was reported that 1,973 people died on the roads in Chile[3]. Carabineros de Chile (Chilean police) reported 89,983 crashes and 57,749 people getting injured[4]. Chile's total population is 19 million.[5] In terms of comparison, Spain reported 1,755 fatal victims from road crashes with a population of 47 million (more than twice than Chile) and a much higher motorization rate.

Despite the dramatic situation, this issue has not been a political priority for Chile. As a result, it is the country that achieved the smallest reduction in terms of number of road fatalities between 1990 and 2018, according to the International Traffic Safety Data and Analysis Group (IRTAD)[6].

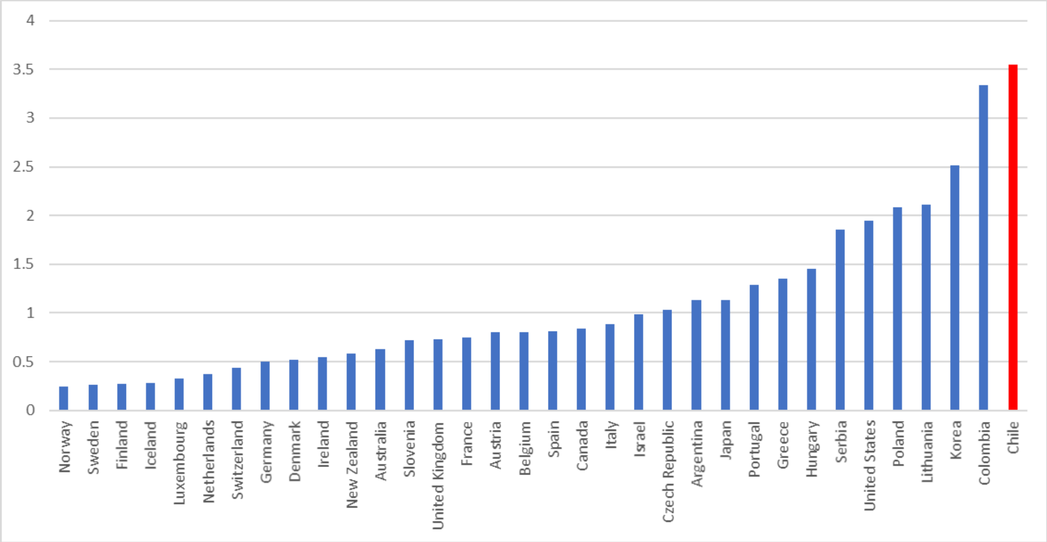
Figure 1: Number of road deaths in Chile, Poland and Spain from 1990 and 2018



Source: Rimbaud, Axel. (2020). Recopilación de datos de Siniestros de Tránsito Chile 2010-2019[7]

Pedestrian fatalities account for 37% of the deaths, thus making Chile the country with the highest rate of pedestrian fatalities in the IRTAD (figure 2).

Figure 2: Pedestrian Fatality rate for 100,000 inhabitant in 2019 in the IRTAD country



Source: data International Traffic Safety Data and Analysis Group (IRTAD)
Own graph, the value for the Netherlands is the most recent available (2017)

The root cause of this lies in the way transport modes are prioritised in Chile. Reductions in travel time,operation costs for motorised vehicles and fuel consumption are the only societal benefits taken into account for the evaluation of most of the transport projects in the country [8] This clearly shows how the Chilean government prioritises motorised transport over pedestrians.

While the national situation has not improved in Chile over the past decades (for instance, 2021 saw the highest road crash fatalities in the last 13 years)[9], certain policies aimed at pedestrian mobility and safety were innovative and saw some positive outcomes. One such policy is implementation of Scramble crossing in 2019.

Figure 3: Exclusive pedestrian phase "Scramble" crossing in Santiago implemented in 2019

Source: Emol

2. Project description

2.1. Background

Another inexpensive yet effective solution to improve pedestrian safety is the so-called “Leading Pedestrian Interval (LPI)”, which has already been implemented in several cities across the world. With this policy in mind, the road safety NGO “Movimiento contra el Exceso de Velocidad Letal” (MEL) published an article about LPI on the 20th of January 2022. Their analysis showed that the first cause of vehicle-pedestrian crashes at intersections with traffic lights was “not respecting the pedestrian right of way, " which highlighted the need for this policy.[10] They then sent a letter to the Chilean Minister of Transports, asking her to evaluate the implementation of a pilot project in Chile. On the 3rd of February 2022, they received a positive response, which stated that “*it seems possible to start the execution of the pilot project during the first semester of 2022*”.The goal of this report is therefore to study the LPI and the effect its implementation could have in the capital city, Santiago.

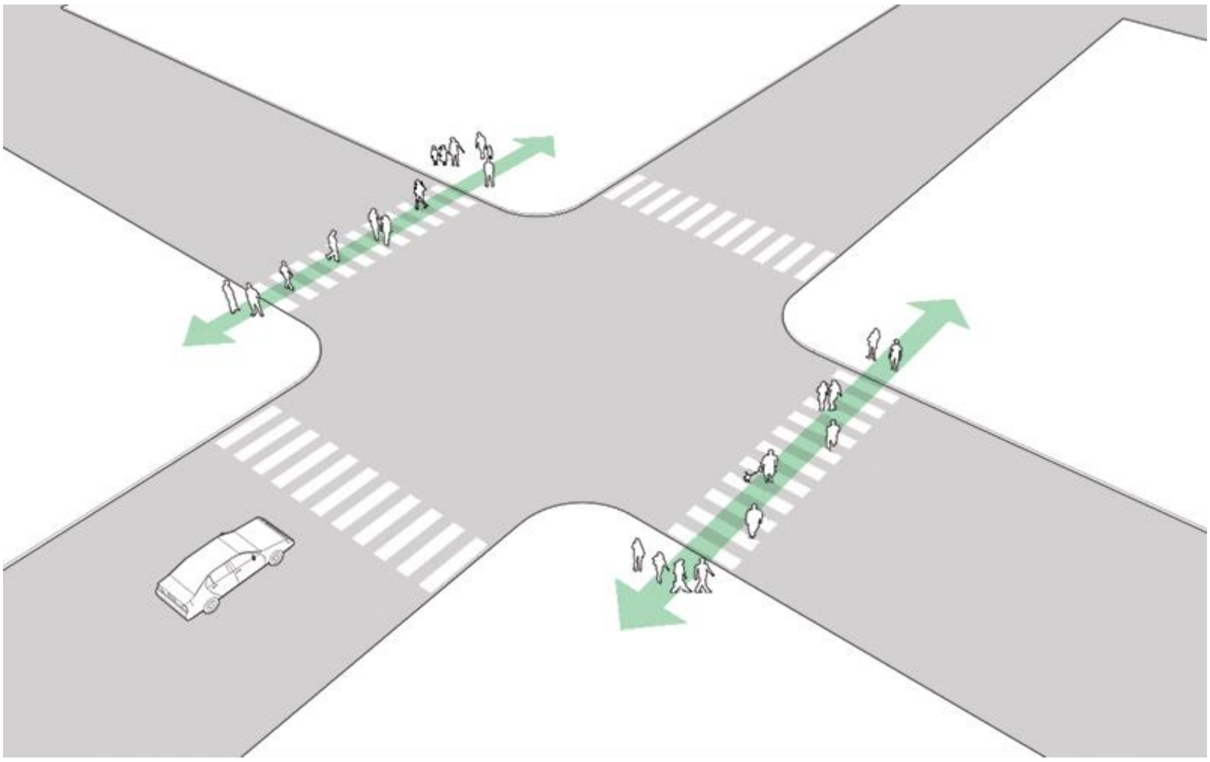
2.2. Leading Pedestrian Interval Overview

As mentioned in the previous chapter, the leading pedestrian interval (LPI) is one treatment that has been implemented at signalised intersections with the goal of improving safety for pedestrians, more specifically to prevent incidents linked to vehicles making outside turns (see *Figure 4, 5 and 6*)[11].

So what exactly is LPI? It is a low-cost adjustment to signal timing to increase pedestrian safety at signalised intersections.

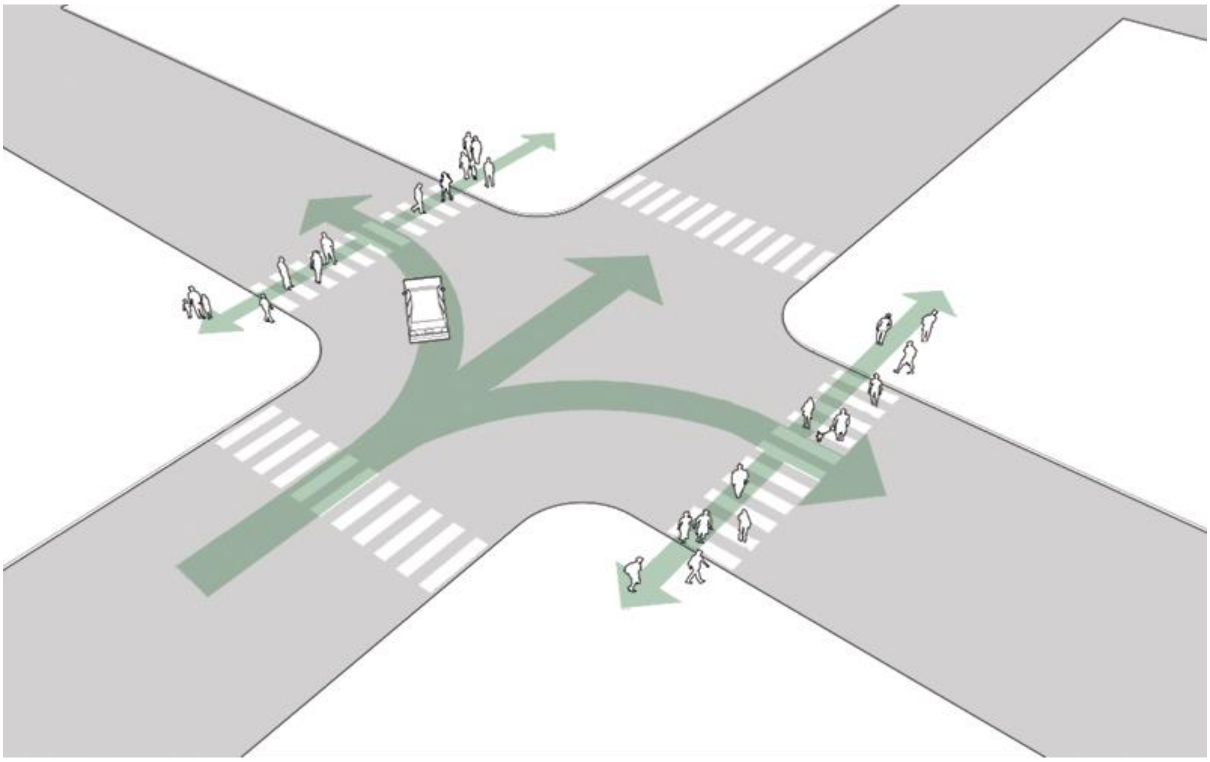
During an LPI, pedestrians receive the walk indication before the start of the green indication for adjacent vehicular movements. The length of the LPI may vary on the basis of site characteristics, but it is generally 3 to 7 seconds in duration. The advance walk interval is intended to improve safety by reducing the potential for crashes between pedestrians and vehicles by providing a brief temporal separation for both road users and increasing the visibility of the pedestrians crossing the street. In addition, the LPI has value in giving pedestrians priority over turning vehicles and encouraging nonmotorized transportation by providing improved pedestrian service at signalised intersections[12].

Figure 4: Phase 1 where Pedestrians are given a 3–7 second head start to enter the intersection.



(Image source: National Association of City Transportation Officials)

Figure 5: Phase 2 Pedestrian and cars have the green light, turning traffic yield to pedestrians already in the crosswalk



(Image source: National Association of City Transportation Officials)

2.3. Previous studies

Little documentation is available on LPI effectiveness. King reports on the safety effectiveness of LPIs at signalised intersections in New York City[13]. The New York State Department of Transportation (NYSDOT) investigated 26 locations with LPIs and compared the crash rates for those locations with those for a group of similar intersections nearby where the LPIs were not implemented (a control group). The crash analysis suggests that LPIs have a positive effect on pedestrian safety, particularly for crashes involving a turning vehicle (28% reduction compared with the rate for control sites and a 64% reduction factored for severity, where fatality = 2,729, serious = 1,214, hospitalised = 303, minor injury = 76, no injury = 1). So, according to this study, it seems that not only LPI is effective at reducing the occurrence of vehicle-pedestrian crashes, but it can also reduce the severity of these accidents.

Unfortunately, the statistical significance of these results was not reported, which makes it difficult to assess the impact of the LPIs. The results also indicated an increase in all injury crashes at the intersections, but again, the significance of these results was not reported. Other sources have indicated a 5% reduction in crashes because of the implementation of LPIs[14]. A case study description of LPI implementation at one location indicated that accident rates remained unchanged at the treatment location. As indicated in the report of that study, the impetus for LPI installation was reactionary and the extent of the crash analysis was not reported[15].

Another important study is the one conducted on 14 stop-controlled intersections within the State College area in Pennsylvania. A before-after with comparison group study design was used to evaluate the safety effectiveness of the LPI implementations. The results suggest a 58.7% reduction in pedestrian-vehicle crashes at treated intersections, which is statistically significant at the 95% confidence level[16].

The City of Toronto, Ontario, Canada, implemented and formally evaluated an LPI in 2005[17]. An evaluation of one of the four existing LPIs in Toronto at University Avenue and Adelaide Street is consistent with the general findings of the literature review and revealed that there was a statistically significant reduction of 34% in non yields immediately after and 61.0% 4 months after implementation of the LPI (see Figure 7).

Figure 7: Nonyield behaviour at University Avenue and Adelaide Street before and after LPI implementation

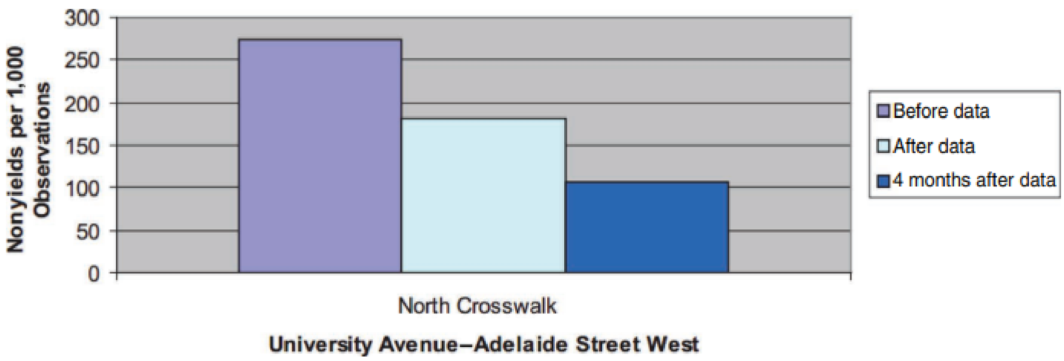


Image source: Saneinejad, S., & Lo, J. (2015). Leading Pedestrian Interval: Assessment and Implementation Guidelines. Transportation Research Record, 2519(1), 85–94. https://doi.org/10.3141/2519-10

Another study conducted on Chicago, Charlotte and New York combined, shows that the effect on pedestrian crashes was generally beneficial, with decreases in pedestrian crashes across all cities. The results in Chicago showed a 19.0% reduction, which was statistically significant at the 95% confidence level. New York sites showed a beneficial but lesser effect on pedestrian crashes, with a 9.0% reduction, but this result was not statistically significant at a 95% confidence level. The result from Charlotte showed a decrease in pedestrian crashes, but this result was highly unreliable given the large standard error. For the combined group of all cities together, the reduction for pedestrian crashes was 13.0%, which was statistically significant at a 95% confidence level.

Table 1: Vehicle-pedestrian crash reduction rate collected from the literature review.

Study	Veh-ped crash reduction rate	Reference
New York City, New York	28.0%	King, M. R. Calming New York City Intersections. Transportation Research Circular E-C019: Urban Street Symposium. TRB, National Research Council, Washington, D.C., 2000.
State College, Pennsylvania	58.7%	Fayish AC, Gross F. Safety Effectiveness of Leading Pedestrian Intervals Evaluated by a Before–After Study with Comparison Groups. Transportation Research Record. 2010;2198(1):15-22. doi:10.3141/2198-03
Toronto, Ontario, Canada	61.0%	Saneinejad S, Lo J. Leading Pedestrian Interval: Assessment and Implementation Guidelines. Transportation Research Record. 2015;2519(1):85-94. doi:10.3141/2519-10
Aggregate result Charlotte-Chicago-NYC	13.0%	Goughnour, E., Carter, D., Lyon, C., Persaud, B., Lan, B., Chun, P., ... & Bryson, M. (2021). Evaluation of protected left-turn phasing and leading pedestrian intervals effects on pedestrian safety. Transportation research record, 2675(11), 1219-1228.

In the CBA, the lowest value of 13.0% is selected to conduct the analysis. This decision was made in order to be conservative with the result and adopt a worst-case scenario approach.

Field evaluations of LPIs have also shown reduced conflicts between pedestrians and turning vehicles. In a study of LPI implementation at three sites in St. Petersburg, Florida, the odds of conflict for pedestrians leaving the curb at the beginning of the walk period were reduced by approximately 95%. The likelihood that a pedestrian would yield to a turning vehicle during the LPI condition also decreased by approximately 60%. The Pedestrian Safety Countermeasure Deployment Project reported a substantial reduction in “vehicles turning in front of pedestrians” and in “pedestrians finishing crossing on the don’t walk indication” at two intersections with LPIs[18]. In a survey of pedestrians during the same study, about 56% of the respondents believed that the signal timing change made them feel “extremely safe” or “more safe”; however, only 8% were able to identify correctly that a change in signal operation had been made. Malenfant and Van Houten have reported that LPIs in combination with other engineering treatments, such as advance stop lines, have had the strongest influence on motorists yielding to pedestrians and in reducing vehicle-pedestrian conflicts[19].

2.4. Side note on vehicle-vehicle crashes

It is worth mentioning that also vehicle-vehicle crashes reduce thanks to LPI[20]. As can be seen in the table below, not only the crash modification factor decreased for vehicle-pedestrian crashes, but also when taking into account the total number of crashes (which includes vehicle-vehicle accidents). As the scope of the research is to investigate a policy aimed at preventing pedestrian injuries and since little literature is available that extensively covers vehicle-vehicle accidents, this factor is not considered when the Cost-Benefit Analysis is performed in the next chapter of the report.

Table 2: Estimated CMFs for LPI Evaluation

City	Treatment sites	CMF for total crashes (SE)	CMF for total injury crashes (SE)	CMF for vehicle–pedestrian crashes (SE)
Chicago	56	0.90[a] (0.027)	0.83[a] (0.046)	0.81[a] (0.070)
New York City	42	0.84[a] (0.031)	0.86[a] (0.037)	0.91 (0.062)
Charlotte	7	0.90 (0.09)	1.09 (0.18)	0.54 (0.38)
All cities combined	105	0.87[a] (0.02)	0.86[a] (0.03)	0.87[a] (0.05)

Note: CMF = crash modification factor; LPI = leading pedestrian interval; SE = standard error
[a]A CMF that is statistically significant at a 95% confidence level.

Image source: Goughnour, E., Carter, D., Lyon, C., Persaud, B., Lan, B., Chun, P., Hamilton, I., Signor, K., & Bryson, M. (2021). Evaluation of Protected Left-Turn Phasing and Leading Pedestrian Intervals Effects on Pedestrian Safety. Transportation Research Record, 2675(11), 1219–1228. https://doi.org/10.1177/03611981211025508

2.5. Objectives

The objective of this report is to analyse the costs and benefits of implementing LPI at signalised intersections in Santiago de Chile, identify which intersections would be the most suitable to be part of the pilot for the introduction of this policy, and finally provide the policymakers with a decision-support tool to further guide the decision on which locations, among the ones filtered by the CBA, should be taken into consideration for the implementation of LPI.

3. Cost Benefit Analysis

3.1. Methodology

The official evaluation methodology of social transport projects in Chile takes as benefits travel time reduction, reduction of operation cost for motorised vehicles, and reduction in fuel consumption. It is possible to present and defend another methodology but it is hard for municipalities with little resources to do so. As this methodology definitely does not take into consideration all the social factors, we will add other parameters that make more robust the analysis and that are presented in the following section.

The main benefit from this intervention is to improve road safety. By considering the effect of the LPI study in the previous section and value of crash, injury, and life loss avoided, below are benefits of Implementation resulting from the reduction in crashes:

- Reduction in fatalities caused in intersection crash
- Reduction of injuries (mild to serious)
- Reduction of material damage to vehicles & property

Cost of implementation are majorly secondary economic impact of delay for vehicle riders:

- Cost of signal reconfiguration
- Cost of travel time delay from non-turning car riders
- Cost of additional idling fuel consumption at the intersection
- Cost of additional idling CO_2 emission at intersection

3.2. Data Used and assumptions

3.2.1. Benefits

Number of road Crashes

To calculate the number of crashes for each intersection, the historical data from the Chilean commission for road safety (CONASET) were used, which received its data from Carabineros de Chile (Chilean police). This is data from the past, and we estimate the number of pedestrians impacted in one intersection per year in the future as the average number of pedestrians killed, injured or run over in intersections with working traffic lights from 2015 to 2019, and we multiply this value by the increase of pedestrian impacted between 2010-2014 and 2015-2019.

Table 3: Overall number of pedestrians fatalities and injuries level at traffic lights in 2010-2014, 2015-2019 in Chile

	Fatalities	Severe Injuries	Less Severe injuries	Mild Injury	No Injury
2010-2014	341	1787	627	5514	8761
2015-2019	348	1985	632	6174	9825
Increase	2%	11%	1%	12%	12%

Table source: Own elaboration, data Carabineros de Chile - CONASET

This data has various issues, firstly the fatalities are only reported until 24 hours (48 hours in 2019) after the crash occurred, victims who received severe injuries and died after a few days will therefore be marked as severely injured and not a fatality.

Secondly, to identify location, we used the name of the streets involved however 57% of the intersection do not have both value, some because they use the information about RUTA (highway) instead of street, some because it was not sent to CONASET and finally were not filled by Carabineros de Chile.

Finally in the road crashes database, the “probable” cause of the road crashes is available. It is therefore possible to use the probable cause “not respecting the pedestrian right of way” which should be partly solved by the LPI. This value is not used in the CBA as the available literature does separate those kinds of crashes but this data will be made available to the Chilean authority and might be useful when choosing the best intersections.

Social Benefit of Road Crashes avoided

Even if the Chilean Ministry of Social Development does not use the improvement of road safety in its recommended process for the transport policies, they published 2017 a study on the value of life lost. The conclusion of this study is that life lost in a road crash in Chile cost 81.739 UF (Unidad de Fomento - which is a non-circulating currency constantly adjusted for inflation) which is equivalent to 3.2 million US dollars (We will use the value of UF on 18th of February 2022 of 39,27 US$).[21]

For the social benefit of injuries and material impact of crashes avoided, we use the evaluation social of road crashes done by the Chilean Road Safety Commission (CONASET).[22] However the value of injuries is really low, no value is considered for long-term injuries cost and it also does not take into account the cases where some serious injuries end up being fatalities (as the fatalities are not counted until 30 days). For those reasons, our model used Jones-Lee et al (1995) and set the value of long term injuries as 0,117 times the value of fatality.[23]

As the value we are using is the potential change in the number of pedestrians impacted, we also need to get the number of vehicles involved in a crash with pedestrians. The data shows that there are 0.66 light vehicles and 0.15 heavy vehicles per pedestrian run over. This gives us an average material value of 16.12 per pedestrian impacted.

3.2.2. Costs

The cost of implementing the LPI in State College, Pennsylvania, was 1,000 USD per intersection in 2005. This would correspond to 1,440 USD in 2022, when adjusted for inflation. The cost included controller programming and the additional cabinet wiring required to accommodate the existing controller assembly. The costs to implement the LPI in a new controller assembly in a shop before installation would likely be much less[24].

Vehicle Flow:

We use vehicle flow data from 2020 research in Santiago [25] to obtain adjusted flow in vehicles per hour on single lane road on the streets in chile. The data gives us riders per hour as the flow during specific hours in morning and evening peaks. We use a factor of 1.7 adopted by the US Department of Transportation (FHWA) to convert to vehicle per hour. We also use multipliers given by FHWA to convert this into a daily average flow.

The obtained information is now used to obtain flow on multi lane roads by adding an assumed factor of 0.6 to the flow for every new lane that is added. The assumption is supported by the fact that some inner lanes in Chile are reserved for buses and taxis and see lower flow of regular vehicles, which mostly use them for turning. On average ratio of turning vehicles at intersections is 0.36 and it reduces for vehicles on the inner lanes[26]. Using this we obtain the number of vehicles that are affected by delayed green light in terms of vehicles per hour.

Going further, we use the vehicle flow to calculate the time cost and emissions cost for vehicles going straight upon LPI implementation.

Vehicle delay cost:
Implementation of LPI affects the vehicles going straight from the traffic signal by causing a delay in the travel time. Waiting for additional 3-7 seconds hence adds on to the cost of the policy here. This can be evaluated by calculating cumulative increase in time cost for the selected traffic intersections. In order to be on the safe side, the proposed model uses 7 seconds delays for all intersections.

The value of travel time saved (VTTS) used is the official one, from the Chilean Ministry of Social development, 2434 CLP/h/pax (3.04 USD/h/pax - CLP to USD).[27]

Vehicle idling Cost:
Additional cost that we encounter with this policy is the impact of extra 3-7 idling for straight moving vehicles. Primary impact is the cost of additional fuel consumption. For calculating we use 0.279 cc/second as per standards of the US department of Energy. Secondary cost impact comes from increase in idling emissions and is calculated as per same standard at the rate of 0.588 g/second.[28]

3.3. CBA Results

As the implementation cost of the project, we are doing all the CBA calculation for the first year and not using any SDR (Social Discount Rate).

Table 4: Cost Benefit Analysis results for the first year

	Highest potential intersection	**Top 10 highest potential intersections**	**Top 100 highest potential intersections**
BCR	**6,17**	**4,7**	**2,78**
Benefit	**236.904 USD**	**1.851.492 USD**	**10.961.612 USD**
Cost	**38.374 USD**	**391.111 USD**	**3.940.368 USD**
Fatalities avoided	**0,085**	**0,5**	**3,05**
Serious injuries avoided	**0,173**	**0,6**	**3,03**
Less serious injuries avoided	**0,052**	**0,156**	**0,598**
Mild injuries avoided	**0,378**	**0,9**	**4,426**
Pedestrian/vehicle crash avoided	**0,67**	**2,3**	**12,03**

The observed results shown in the table no # reflect the top intersections in terms of the Benefit to Cost Ratio (BCR), meaning implementation at these intersections are economically more feasible. As we zoom out to say top 10 or top 100 intersections, the average BCR decreases as intersections with lower potential are added, however the absolute reduction in crashes and subsequently injuries and fatalities per intersection increases. It is interesting to note that the first 160 intersections have a BCR higher than 1. The bottom half of the table highlights the impact of LPI in reducing fatalities, injuries and material damage which translates into the benefit here.

3.4. Sensitivity and Risk assessment

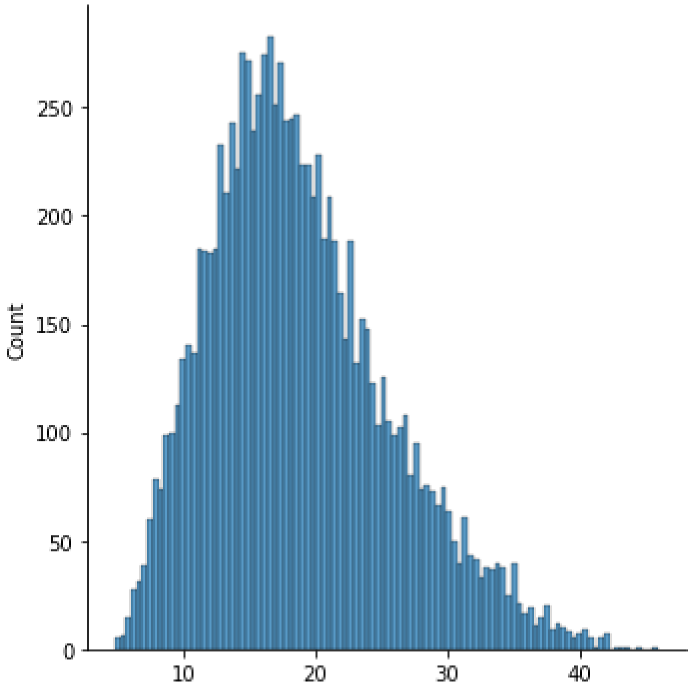
3.4.1. Monte Carlo Simulation

As the created model used some specific values for important parameters like the value of long-term cost of serious injuries, the impact of the LPI and the duration of the LPI. A Monte Carlo Simulation with 10.000 was performed on the highest, top 10 and top 100 potential intersections modifying the value of those 3 parameters in the following way:

- LPI duration: a uniform distribution between 3 and 7 seconds was used, instead of 7 seconds in the model
- The Social cost of serious injuries: a uniform distribution between 0 and 0.117 times the Value of Life was used, instead of later in the model
- Effect of policy: taking into account all the studies revised in part 2, a triangular distribution with a minimum of 13% a mean of 40,2% and maximum of 61% was used instead 13% in the model

The results for the simulation of Top 10 highest potential intersections can be seen in figure 7, the model created was really conservative and the simulation gives BCR much higher with a mean of 18,7 and a median of 17.7. The distribution is similar for the highest potential intersection and the top 100. The mean of a distribution for highest simulation is 22,7 with a median is 21,5, and finally for the top 100 the mean 11,3 is and the median is 10,8.

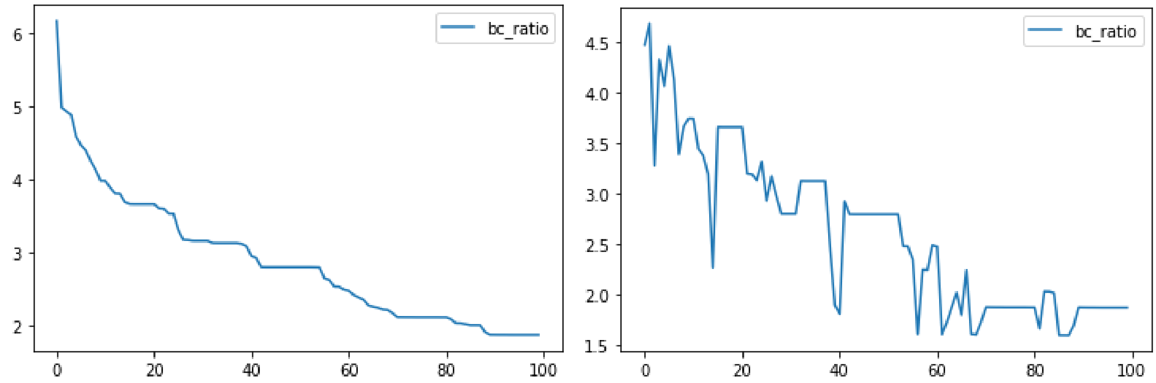
Figure 7: Monte Carlo Simulation of the BCR for the Top 10 highest potential intersections



3.4.2. Injury cost

On top of this previous Monte Carlo simulation, an sensibility analysis was performed individually on the 3 parameters mentioned in the previous section. The result for the social value of injury gave interesting results as it changes the ranking of the intersections. It can be seen in figure WW.

Figure 8: BCR value of the Top 100 highest potential intersections with 0,117 times the value of life as the value for serious injury (left) and with 0 as the value of serious injury (right)



3.5. Sanity checks

To validate the CBA results, the 10 intersections with the highest BCR were examined using google maps. They are listed in the following section.

Table 5: Sanity check analysis for top 10 most affected intersections

	Intersection	Municipality	Images	Comment
1	Gran Avenida José Miguel Carrera and Americo Vespucio	La Cisterna	 Image source: Google Maps	This intersection ihas with traffic with the highest number of pedestrians impacted by motorised vehicles, however it does not seem suitable for the implementation of a LPI as there are dedicated turning lanes. It is interesting to note that those turns are not regulated by a traffic light but by a simple pedestrian crossing which is probably not safe. Also this Intersection is part of an existing project to make the surrounding Multimodal station of La Cisterna safer and more accessible. .

2	Eyzaguirre and Santa Rosa	Santiago	 Image source: Google Maps	This intersection has a very high BCR as it has a small cost (few one way lanes) and high benefit (2 fatalities) in our model. However 2 of the 3 pedestrians victims of road crashes in this intersection, were two young sisters (Isabel and Eugenia), who were run over by a bus driver who did not respect the red light.[29] Even if this intersection seems suitable for a LPI, the possible benefit of the LPI might be overestimated.
3	Cardinal José Maria Caro and Independencia	Santiago	 Image source: Google Maps	A LPI does not seem relevant for the intersection # 3 as there are two roads merging into one and the pedestrians and the car should not have green lights at the same time in the same space.
4	Libertador Bernardo O'Higgin, General Velasquez	Estacion Central	 Image source: Google Maps	The implementation of a LPI in this intersection seems highly relevant as it is the intersection between two important roads with high level of turn. One thing however is the avenue General Velasquez is the motorway underneath the intersection and that the intersections are between the avenue Liberador Bernardo O'Higgins and avenue Padre Alberto Hurtado. This seems to be an issue with the data.
5	Goycolea and Gran Avenida José Miguel Carrera	La Cisterna	 Image source: Google Maps	Intersection between two important streets with pedestrians and turning vehicles. Seems highly suitable for the implementation of a LPI. This intersection is close to the Multimodal station of La Cisterna which is part of a project to make it more accessible.
6	Liber Bernardo O`higgins and Portugal	Santiago	 Image source: Google Maps	End of an important road, connecting an even more important road, with high levels of pedestrian and turning vehicles. Seems highly suitable for the implementation of a LPI.

7	Manuel Antonio Matta and Sta Rosa	Santiago	 Image source: [Google Maps]()	Intersection between two important streets with pedestrians and turning vehicles. Seems highly suitable for the implementation of a LPI.
8	Jose Luis Coo and Balmaceda	Puente Alto	 Image source: [Google Maps]() 	Intersection between two one way roads, high pedestrian flow and turning vehicles. On each side of the intersecion a sign to “remind” the pedestrians to cross at the green light is installed, this seems to show that there are high conflicts between pedestrians and vehicles.
9	José Joaquin Prieto Vial And Departamental	Pedro Aguirre Cerda	 Image source: [Google Maps]()	Intersection between a main road and road going along and accessing an urban motorway. LPI seems suitable for this intersection
10	Santa Rosa Batallon and Chacabuco	La Pintana	 Image source: [Google Maps]()	Intersection between the end of a secondary road and a main road with a dedicated bus corridor with pedestrians crossing the main road to access public buses. LPI seems especially suitable here as it will protect the pedestrian accessing public transport from the flow of vehicles turning on the main road

Those 10 first intersections are an encouraging result as most of them seem relevant for the implementation of a Leading Pedestrian Interval, however it seems that the CBA does not take into account all the factors which can determine if an intersection is the most suitable for the implementation of a LPI. In the following section some more parameters will be evaluated to select the best intersection out of the high potential intersections revealed by the CBA.

4. Multi Criteria Decision Analysis (MCDA) for the decision maker

Following the CBA results, this evaluation sets up as a second filter through a Multi Criteria Decision Analysis (MCDA) for the decision makers implementing the LPI policy in Chile. To do so, an in-depth evaluation of some parameters not included in the CBA, and some others included, will be carried out through a Simple Multi-Attribute Ranking Technique (SMART), in which the parameters in the most affected intersections in Chile are compared.

SMART is an MCDA analysis tool based on a linear additive model. Its worth stems from the fact that decision makers can reveal their preferences, allowing for a better understanding of the decision problem and supports the final resolution. SMART can be used in a variety of decision-making applications, and the method is typically divided into nine stages. It is important to understand that the decision-making process is frequently iterative with the decision-maker going back and forth between the various stages[30]. The nine stages are as follows:

Step 1: Identify the person or agency whose utilities are to maximize: The Traffic Control Operational Unit from Chile (UOCT in Spanish)
Step 2: Identify the issue: Reduce crashes in intersections where pedestrians are involved.
Step 3: Identify the alternatives to evaluate and add their values:

- Crash/casualty rate
- Vehicle Demand
- Pedestrian Demand
- Turns with conflicting interactions between users
- Existence of nearby centers of attraction
- Traffic light cycles times
- Number of existing traffic lights cycles
- Intersection size
- Congestion levels

Step 4: Identify the relevant dimensions of value for evaluation of the alternatives: Top ten most affected intersections)
Step 5: Rank the dimensions in the order of importance: Ranked by the CBA and Sanity results
Step 6: Rate dimensions in importance, preserving ratios. The most important dimension would be assigned a value of 100. The next-least-important dimension is assigned a number reflecting the ratio of relative importance to the least significant dimension: This step has to be done by the decision maker.
Step 7: Sum the importance weights, and divide each by the sum. This allows normalization of the relative importance into weights summing to 1.0: This step was done by asking different stakeholders to rank the 9 parameters from highest to lowest. The method and results are explained below.
Step 8: Calculate Utilities for alternatives

$$U_j = \sum_{k} . w_k u_{jk} \quad \text{Eq.(1)}$$

Where Uj is the utility of alternative j,
wk is the normalized weight for objective k,
Ujk is the scaled value for alternative j on dimension k.
$\sum k . wk = 1.$
The wk values obtained from Step 7 and the ujk values generated in Step 8

Step 9: Decide. If a single alternative is to be selected, choose the set of alternatives with maximum *U*

The Traffic Control Operational Unit from Chile (UOCT) is the entity who will be conducting the development and implementation of the project, and to support them with the decision making a survey was prepared and sent to different relevant stakeholders. All stakeholders had to rank all nine parameters from highest to lowest relevance according to the deployment of an LPI policy. The survey was answered by civil society organizations related to car drivers, accessibility, road safety, and pedestrians, Among them: Movimiento contra el Exceso de velocidad Letal (Movement against Lethal Overspeed), "Corporación Ciudad Accesible" (Accessible City Corporation), "La Reconquista Peatonal" (Pedestrian Reconquest), "Fédération International de L'automobile"(International Federation of Automotive)/ "Club del Automóvil chileno" (Chilean Vehicle Club), and public entities as the "Comisión Nacional de Seguridad de Tránsito" (National Traffic Safety Commission), "Unidad Operativa de Control de Tránsito" (Traffic Control Operational Unit from Chile).

The overall weight value of all parameters was done by summing up all the values assigned by the stakeholders times the number of repetitions. As a result, the alternatives were ranked and calculated (Step 5 and 7) as in the following table:

Table 6: Parameters weight (Step 7)

Attributes	Weights	Standard weights
Crash/Casualty rate	50	15,8
Turns with conflicting interactions between users	44,5	14,1
Traffic light cycle times	38	12,0
Congestion levels	35	11,1
Pedestrian demand	34	10,7
Intersection size	34	10,7
Existence of nearby centers of attraction	28	8,8
Vehicle demand	27	8,5
Number of existing traffic lights cycles	26	8,2
Total	**316,5**	**100,0**

The SMART evaluation is presented as a second filter to select among the most affected intersections resulting from the CBA. It is worth mentioning that the analysis is partially developed and that it is the responsibility of the decision maker to complete the missing steps. In this case, he/she must acquire the values of each parameter for each of the 10 intersections (step 3), rate dimensions in importance, (step 6), calculate the utilities (step 8) and make the decision. Within the framework of this evaluation, it was decided to estimate the values of the nine parameters for two of the potential intersections in order to present the SMART methodology to the authorities in charge of the implementation of the pilot.

Following the sanity check, intersection 2 and 4 are both the most suitable intersections to choose among the 10 most affected. We estimate the values for each option, compute each alternative ratios and then calculate intersection utilities. The results show that intersection 4 has a higher utility, therefore it would be the most suitable intersection to start with the implementation of the pilot project.

It is worth noting that the utility was calculated using an estimate of the values for each parameter and alternative. It would be up to the decision maker to collect the missing information, follow all of the SMART method steps, and calculate the utility using real data.

Table 7 : SMART utilities for intersection 2 & 4 (Step 6 & 8)

	Crash rate (Benefit)	Vehicle demand (Vehicles/hour)	Pedestrian demand (p/h/m)[31]	Turns with conflicting interactions between users	Existence of nearby centers of attraction	Traffic light cycle times (sec)[32]	Number of existing traffic lights cycles	Intersection size (meters)	Congestion levels (Roadway Level-Of-Service (a-f)	
Intersection 2	1814570671	375	0,030	2	low	36	3	29,3	B	
Intersection 4	2887358163	616	0,0616	3	high	60	3	62,6	E	
Total	4701928834	991	0,092	5	0,0	96	6	91,9	0,0	
	Crash rate (ratio)	**Vehicle demand (ratio)**	**Pedestrian demand (ratio)**	**Turns with conflicting interactions between users (ratio)**	**Existence of nearby centers of attraction (ratio)**	**Traffic light cycle times (ratio)**	**Number of existing traffic lights cycles (ratio)**	**Intersection size (ratio)**	**Congestion levels (ratio)**	**Total Sum**
Intersection 2	0,4	0,4	0,3	0,7	0,2	0,4	0,5	0,32	0,3	39,68
Intersection 4	0,6	0,6	0,7	0,6	0.8	0,6	0,5	0,68	0,7	57,28
Standard weights	15,8	8,5	10,7	14,1	8,8	12,0	8,2	10,7	11,1	

5. Discussion: Policy Implications

5.1. Social Cost of Injuries in Chile

As there are no value official from the Ministry of Social Development for the social cost of injuries produced by a road crash, we used the values from the annual evaluation of the social cost of road crashes done by the CONASET, those values are really low compared to the values of fatality and do not take into account the long term cost of injuries.

Table 8, highlights Chilean valuation of injury cost with the evaluation made in Sweden (which is an example for road safety worldwide), we can see that Cost of Injury is heavily undervalued compared to Sweden. While the ratio of fatalities to very severe is reasonably 2.82 in Sweden, the fatality to Serious Injury ratio is 613 for Chile which highlights the undervaluation. New York based research by King, further emphasises the above with fatality to serious injury ratio being 2.25 (relative values: Fatality: 2,729, serious: 1,214, hospitalised: 303, minor injury: 76, no injury: 1).

Table 8: Ratio between material damage, injury and fatality cost in Sweden and Chile

Sweden	**Material Damage**	**Non severe**	**Severe Injury**	**Very Severe**	**Fatality**
Material Damage	1.000	0.003	0.001	0.001	0.000
Non severe	306.667	1.000	0.387	0.259	0.092
Severe Injury	792.000	2.583	1.000	0.668	0.236
Very Severe	1186.000	3.867	1.497	1.000	0.354
Fatality	3350.000	10.924	4.230	2.825	1.000
Chile	**Material Damage**	**Mild Injury**	**Less Serious injury**	**Serious injury**	**Fatality**
Material Damage	1.000	3.328	2.551	0.694	0.001
Mild Inury	0.300	1.000	0.766	0.209	0.000
Less Serious injury	0.392	1.305	1.000	0.272	0.000
Serious injury	1.440	4.793	3.673	1.000	0.002
Fatality	882.672	2937.593	2251.481	612.952	1.000

Source: Own table, Chile: CONASET, 2021, Evaluation Social of Road crashes 2020
Sweden: Swedish Transport Administration, 2020, Road safety and crashes costs

This can be explained partly by the difference in the definition of injury between Chile and Sweden. In Chile a serious injury is an injury which forbids a person to work for more than 30 days[33], while in Sweden a severe injury is defined on its long term consequences as it is the injuries which give at least 1% but less than 10% permanent medical disability[34]. However, this difference of definition does not explain in itself such an important gap, for instance Serious injury in Chile is valued as a bit more than 1,4 no injury crashes while an Non-Severe injury in Sweden is valued as 307 no injury crashes.

Additionally, material cost is valued highly in Chile (fatalities cost to Material damage cost ratio is only 883 compared to 3350 in Sweden). Material damage cost is valued higher than costs of less Serious injury which is another major challenge with Chile's social cost valuation method.

It seems like the social cost of the injuries is undervalued in Chile and it would be beneficial for the Ministry of Social Development to evaluate the value of injuries produced by road crashes.

5.2. Road crashes data incomplete

As it was mentioned in the CBA part of this section, the road crashes data have various problems and it seems it is especially bad outside of the capital Santiago. This is probably one of the reasons why the most valued intersections are in Santiago and it would be important for the Chilean police to improve the reporting and geolocalization of the road crashes.

5.3. Equity

It is interesting to note that in Chile there exists an inverse relationship between pedestrian road safety level and socioeconomic level of a municipality (Fresard et al 2017).[35] This can be explained by the difference in the safety level of the pedestrian infrastructure or lack of illumination. Some indirect effects like the access and quality of healthcare after the crash play also a role.

Therefore it would be important to consider the implementation of the LPI as a method to increase the level of safety in municipalities with less resources and therefore reduce equity gaps.

5.4. Pedestrian Comfort relationship with Walkability, link to pedestrian

Apart from benefits that have been translated to cost in the CBA, the introduction of LPI has a secondary benefit of reducing pedestrian anxiety at the crosswalks and enabling a safer walking environment. Enhancement in pedestrian comfort is a key benefit that can be used for CBA/MCDA if correct valuation of the same is identified and shared by respective country authorities.

Pedestrian safety comfort is closely related to walkability index of urban space and LPI helps with making urban Chile more walkable. As per Villaveces et al (2012)[36] walkability as a metric is dependent on traffic safety along with crime safety and neighbourhood characteristics.

6. Conclusion

Road traffic crashes are the leading cause of fatalities for age groups of 5 to 29 years. This means traffic crashes have a higher effect on years of overall lives lost. Chile has not been able to curb down the rates and rather 2021 was the peak year in terms of traffic fatalities in the countries. Pedestrians represent 37% of these fatalities and are the most vulnerable groups in mixed traffic.

Leading Pedestrian Interval, amongst others, is a low cost measure toward reducing vehicle-pedestrian crashes and hence reducing the burden of injuries and fatalities. The planned pilot for LPI is expected in early 2022 and this report assessed the LPI implementation for different intersections in Chile using the project valuation tools that take into account socio-economic parameters.

Cost Benefit Analysis by itself considers effects which can be treated in monetary terms and gives a high level idea of potential intersections from socio-economic benefits perspective. General conclusion based on the evaluation is that implementation of LPI is economically feasible owing to its low implementation cost and high benefits of reduced life cost. When ranked in order of benefits ratio, the first 160 intersections have a BCR higher than 1.

Furthermore, a decision support tool (MCDA) was presented as an additional filter to select among the intersections with higher potential from the CBA. The results show that intersection 4 has a higher utility, so it would be the best intersection to begin implementing the pilot project. It is worth noting that the utility was calculated using an estimate of the values for each parameter and alternative. It would be up to the decision maker to collect the missing information, follow all of the SMART method steps, and calculate the utility using real data.

Finally, one should note that the real value generation from LPI implementation is reduction of road traffic fatalities and injuries to pedestrians. And pedestrian safety shall be of important consideration for well being and urban living. The results of this report are not only aimed at suggesting better intersections for LPI implementation but also, to highlight use of a better evaluation methodology for road crash injuries for any official project purpose.

7. Next steps

As mentioned earlier in the report, a Leading Pedestrian Interval pilot project should start in Chile during the first half of 2022. Our report and data should be shared with the Ministry of Transport in order to help them define the details of the implementation.

Also, a letter should be sent to Carabineros de Chile to ask them to improve the reporting of the road crashes data and make it more consistent, especially outside of Santiago.

Finally, a letter shall be sent to the Chilean Ministry of Social development, asking them to review their methodology of Project Social Evaluation, always taking in account Road Crashes changes, evaluating the long term cost of injuries and adding other parameters like Local pollution, Noise or CO_2 emissions.

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