An analysis on health care costs due to accidents involving powered two wheelers to increase road safety

Maria Vittoria Corazza a,*, Antonio Musso a, Kostas Finikopoulos a, Veronica Sgarra a

Department of Civil and Environmental Engineering – DICEA, Sapienza University of Rome, Via Eudossiana 18, Rome 00184, Italy

Abstract

Powered Two Wheelers (PTWs) provide a convenient mode for a large portion of population in many cities. At the same time PTWs present serious system problems, the most important being poorer safety if compared to other motorized modes. But even when lower safety levels are acknowledged, problems behind are far from being solved. Rome is an example: although PTWs accidents rates are not negligible, the need for a specific safety policy is still unmet. Therefore the local Mobility Agency appointed the authors of this paper for a study of PTWs accidents occurring in the urban area. An assessment of the associated health care costs was also required. The objective of the paper is to report the main outcomes of this study highlighting recurring features of PTWs accidents, the high health care costs and how to quantify the economic resources to improve safety. The methodology was based on three steps: i) an analysis of the causes of PTWs accidents, which resulted into the location of black spots and assessment of the severity of the events; ii) the estimation of health care costs after a scientific literature review; iii) the association of health care costs to black spots and accidents severity to rank interventions to improve PTWs safety. This led to a final list of roads where PTWs accidents of the highest severity occurred and the required economic resources to improve their safety level. This stressed, for the first time, the unaffordable expenditures due to PTWs accidents. In conclusion, the issue whether the awareness of such costs can be used as leverage for more mindful behaviors among the riders is addressed.

© 2016 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Keywords: road safety; Powered Two Wheelers; health care costs; safety potential index

* Corresponding author. Tel.: +39-06-44585736; fax:+39-06-44585146.
E-mail address: mariavittoria.corazza@uniroma1.it
1. Introduction

The magnitude of the overall road safety crisis is largely acknowledged worldwide: according to the World Health Organization (WHO) “the economic consequences of motor vehicle crashes have been estimated between 1% and 3% of the respective GNP of the world countries, reaching a total over $500 billion” (WHO 2010).

Still, decision-makers seem to underestimate the relevance of public health care costs to recover and rehabilitate those involved in road accidents. For what strictly concerns PTWs, there are many contributing factors. At national level, emphasis is obviously placed on prevention, thus enforcing stricter and stricter regulations to mandate comprehensive sets of safety measures (for example compulsory helmets; restrictions for novices; vehicle improvements such as enhanced brake systems or anti-tampering measures, etc.). Not the same can be said in terms of efforts to promote and enforce effective and consolidated post-crashes response procedures. According to the WHO (2013), if considering the Countries with >1,000,000 inhabitants and with riders accounting for about > 1/3 the deceased (table 1), it is clear that the quality of post-crashes care response procedures is far from being adequate (also in some high income countries).

At local level, reasons of underestimation rely on the general approach to mobility problems, as policies with respect to the use of two-wheelers and whether special facilities should be provided are typically non-existent. The involvement of Powered Two-Wheelers (PTWs) in mobility plans is quite rare, being this mode considered by decision-makers as either not a priority (when PTWs are not among the dominant modes) or too sensitive to reach consensus (in areas where they are dominant, as observed in Musso et al. 2010).

Table 1. Countries with PTWs highest fatality rates.

| Country                  | PTWs as dominant mode (Yes/No) | Helmet wearing rate (%) | Deceased drivers/ passengers of PTWs (% of all reported road traffic deceased) | Post-crashes care response procedures | Emergency medicine training (Yes/No) |
|--------------------------|---------------------------------|-------------------------|---------------------------------------------------------------------------------|--------------------------------------|-------------------------------------|
|                          |                                 | Driv.  | Pass.  |                                 | Doctors transported by ambulance (%) | Emergency doctors | Emergency nurses |
| Laos**                   | Yes                             | 75     | n.a    | 74.5                             | ≤10                                  | Yes                  | No                |
| Thailand**               | Yes                             | 53     | 19     | 73.5                             | 50–74                                 | Yes                  | No                |
| Cambodia*                | Yes                             | 65     | 9      | 66.6                             | 11–49                                 | Yes                  | Yes               |
| Malaysia**               | Yes                             | 76     | (all riders) | 58.7                           | ≥75                                  | Yes                  | Yes               |
| Dominican Republic**     | Yes                             | n.a    | n.a    | 57.8                             | n.a                                  | Yes                  | No                |
| Benin***                 | No                              | n.a    | n.a    | 50.2                             | -                                    | Yes                  | Yes               |
| Singapore*               | No                              | n.a    | n.a    | 46.1                             | ≥75                                  | Yes                  | Yes               |
| Paraguay**               | No                              | 45     | 20     | 41.4                             | 50–74                                 | Yes                  | No                |
| Colombia**               | Yes                             | 99     | 40     | 39.1                             | 11–49                                 | Yes                  | Yes               |
| Pakistan**               | Yes                             | 10     | (all riders) | 38.6                           | 11–49                                 | Yes                  | No                |
| Indonesia**              | Yes                             | 80     | 52     | 35.7                             | ≤10                                  | Yes                  | Yes               |
| Cyprus*                  | No                              | 75     | 68     | 35.0                             | ≥75                                  | No                   | No                |
| China**                  | n.a                             | n.a    | n.a    | 34.5                             | ≥75                                  | Yes                  | Yes               |
| India**                  | Yes                             | 50     | ≤10    | 32.4                             | 11–49                                 | Yes                  | Yes               |
| Greece*                  | No                              | 74     | 34     | 30.6                             | n.a                                  | No                   | No                |
| Italy*                   | No                              | 92     | (all riders) | 30.3                           | n.a                                  | Yes                  | Yes               |
| Guatemala**              | No                              | 40     | (all riders) | 30.0                           | ≥75                                  | Yes                  | No                |

Income: *high, **middle, ***low
2. PTWs in Rome, main facts and figures

Although road safety has become a central issue in the Italian political agenda and the consequent awareness of the higher vulnerability of PTWs increased, Rome is no exception in the lack of a proper approach to PTWs safety problems and the local situation reflects contradictions and efforts to manage a locally very popular mode of transportation in an urban context where policies to achieve more sustainable mobility patterns still do not fully succeed.

The city’s vehicle ownership rate, as recorded in 2013, is one of the highest in Europe: 917.6 vehicles (two-wheelers included) per 1000 inhabitants (including the infant and senior populations). The estimated number of two-wheelers is about one for every five inhabitants (Rome Municipality 2009). PTWs are part of the mobility of everyday life: more than half of the overall number of trips by two-wheelers occurs in a distance range between 2 and 11 km (just as for cars), and even for walking distances (0 to 1 km), the use of mopeds and motorcycles is still an option (ATAC 2005). This and the high local PTWs fatality rates, i.e. 31.26 fatalities per million inhabitants (Surace et al. 2010), among the highest in Italy (average rate in Italy 19.0 and in the EU-24 12.9, according to ERSO 2012), makes an example of the importance of this issue. According to the Rome Municipality database, a focus on accidents occurred between 2010 and 2012 highlights that: the amount of injured and deceased riders (on both mopeds and motorcycles) is virtually equal to that of drivers, respectively 42.2% and 43.8%; during nighttimes about 1/4 of road users involved in accidents are riders; according to table 2, in general mopeds seem to be quantitatively less affected than motorcycles, but during nighttimes the ratio between event and involvement (both as deceased and injured) is virtually equal to 1 and the vehicle is always damaged.

Table 2. PTWs accidents in Rome, 2010–2012.

| Mode   | Period | 6h31–22h29 | 22h30–6h30 |
|--------|--------|------------|------------|
|        | Year   | Deceased   | Injured    | Events     | Deceased   | Injured    | Events     |
|        |        | (unit)     | (unit)     | (unit)     | (unit)     | (unit)     | (unit)     |
| private cars | 2010 | 18 | 7,420 | 27,816 | 20 | 2,290 | 5,065 |
|         | 2011 | 19 | 7,496 | 27,744 | 22 | 2,213 | 4,936 |
|         | 2012 | 21 | 6,348 | 24,625 | 15 | 1,989 | 4,267 |
| mopeds | 2010 | 6  | 979  | 1,487 | 2  | 133  | 157  |
|         | 2011 | 1  | 969  | 1,414 | 3  | 129  | 172  |
|         | 2012 | 3  | 748  | 1,099 | 1  | 93   | 136  |
| motorcycles | 2010 | 47 | 7488 | 9,605 | 13 | 685  | 774  |
|         | 2011 | 45 | 7906 | 9,991 | 16 | 715  | 815  |
|         | 2012 | 25 | 6382 | 8,260 | 12 | 560  | 627  |
| bicycles | 2010 | 2  | 175  | 214  | 1  | 6    | 9    |
|         | 2011 | 1  | 205  | 263  | 0  | 10   | 16   |
|         | 2012 | 5  | 207  | 283  | 0  | 17   | 20   |
| pedestrians | 2010 | 38 | 2,070 | 2,102 | 11 | 172  | 169  |
|         | 2011 | 45 | 2,040 | 2,100 | 11 | 167  | 163  |
|         | 2012 | 39 | 1,952 | 2,005 | 17 | 159  | 169  |

Strictly focusing on nighttime occurrences, the majority of injured riders involved in an accident is aged between 18 and 29, but those under 18 (mostly minors, as pillion riders) are not a negligible group, especially for mopeds (51% of accidents with injured victims are riders younger than 18 years old). Novices and young riders (< 39 years old) record lower helmet wearing rate than their senior peers, but the overall community is in line with the national rate reported in table 1.
The driving environment (weather conditions, maintenance and quality of the infrastructures, availability and appropriateness of signs and street lighting, level of traffic, etc.) cannot be considered a contributing factor in the occurrence of accidents, as in the overwhelming majority of cases all these aspects were of no relevance; in fact, circumstances could be defined as “ideal” for safe ridership (good weather conditions, roads with good maintenance level, appropriate provision of traffic signs and street lighting, poor occurrence of congestion phenomena). On the contrary, behaviors resulted far from optimal: exceeding speed limits (15% for both mopeds and motorcycles); inattentive driving (respectively 24% for mopeds and 17% for motorcycles); inappropriate behaviors (29% for mopeds and 13% for motorcycles) and sudden braking (13% for mopeds and 21% for motorcycles) are among the most recurring causes of accidents (among which neither DUI nor drink driving are recorded). All of the above stresses how riding during nighttimes is not just a downscaled version of daytime problems, but is an unsafe activity also in light of the reduced amount of circulating vehicles; this prompted the Mobility Agency of Rome Municipality to include this specific safety issue within a more general study to reduce speed in night hours.

Including PTWs in such study meant also the opportunity to in-depth study the specific health care costs related to accidents involving riders for the first time, and address this issue to the road safety inspection processes, so to have a final classification of road sections which result to be unsafe for PTWs and the improvements that can be planned to increase their safety levels.

3. Assessing the health care costs

Scientific literature on social costs of road accidents abounds and so the general estimation procedures for health care costs part of the calculation of the overall road safety social costs (Hakkert and Wesemann 2005, Elvik 1995). The specific “items” which constitute the list of costs differ among the Countries: from first aid to recovery, up to funeral expenses in some cases. But, even when focusing on the four main basic expenditures (First aid and emergency room, Ambulance, Recovery and Rehabilitation) scientific and grey literature show differences in the units of measurements or assessment criteria (table 3).

Table 3. Average health care costs in selected countries.

| Country          | Type of cost and units of measurement | Source                          |
|------------------|-------------------------------------|---------------------------------|
|                  | First aid and emergency room         |                                 |
|                  | Ambulance                            |                                 |
|                  | Recovery                             |                                 |
|                  | Rehabilitation                       |                                 |
|                  | Source                              |                                 |
| Austria          | 54.3 Euro/p                          | Meerding and Toet 2002          |
|                  | n.a.                                |                                 |
|                  | 273 Euro/p per day                  |                                 |
|                  | 207 Euro/p                          |                                 |
| Greece           | 51.36 Euro/p                        | Meerding and Toet 2002          |
|                  | n.a.                                |                                 |
|                  | 142 Euro/p per day                  |                                 |
|                  | n.a.                                |                                 |
| The Netherlands  | 99 Euro/p                           | Meerding and Toet 2002          |
|                  | 143 Euro/trip                       |                                 |
| Spain            | 74.99 Euro/p*                       | Bastida et al. 2004             |
|                  | 20.61 Euro/trip                     |                                 |
|                  | 15,832 Euro/p per stay              | Soriano Somovilla 2010          |
|                  | n.a.                                |                                 |
|                  | From 722.51 to 265.95 Euro/p per    | García Altés and Pérez 2007    |
|                  | severity level                      |                                 |
|                  | 240.09 Euro/p per day               |                                 |
|                  | n.a.                                |                                 |
|                  | From 18,655.26 to 10,660.15 Euro/p  |                                 |
|                  | per year per severity level         |                                 |
| Italy            | 82.99 Euro/p*                       | Chini and Farchi 2011           |
|                  | 24.61 Euro/trip                     |                                 |
|                  | 18,832 Euro/p per stay              |                                 |
|                  | n.a.                                |                                 |
|                  | From 722 to 74 Euro/p per severity  | Lattarulo 2012                  |
|                  | level                               |                                 |
|                  | 142 Euro/p                          |                                 |
|                  | 26 Euro/p                           |                                 |
|                  | 3988 Euro/p                         |                                 |
| United Kingdom   | From 1,067 to 1,298 GBP/p per       | Jeffrey, 2010                   |
|                  | severity level                      |                                 |
|                  | n.a.                                |                                 |
|                  | From 17,421 to 6,413 GBP/p*         |                                 |
|                  | n.a.                                |                                 |
|                  | From 1,006 to 13,671 GBP/p per      | DfT 2013                        |
|                  | severity level                      |                                 |
|                  | n.a.                                |                                 |
|                  | n.a.                                |                                 |
From 54 to 38 USD/p according to gender
From 47.895 to 8.779 USD/p per severity level

From 54 to 314 USD/p per day, per severity level, according to gender

n.a.

Naumann et al. 2010

From 47.895 to 8.779 USD/p per severity level

From 67.565 to 26.871 USD/p per severity level

Malchose, and Vac hal 2010.

From 8.246 to 40 AUSD/p per severity level
From 462 to 336 AUSD/p per severity level
7.114 AUSD/p
2.372 AUSD/event

From 462 to 28 AUSD/p per severity level
From 5,493 to 28 AUSD/p per severity level
90,476 AUSD/per year

Baldock and McLean 2005

Malchose, and Vac hal 2010.

From 600 to 2,009 NZD/p per severity level

n.a.

From 100 to 4,300 NZD/p per severity level

MTNZ 2013

Table 4. Estimated health care costs of accidents involving PTWs in Rome.

| Year   | 2010          | 2011          | 2012          |
|--------|---------------|---------------|---------------|
| Period |               |               |               |
| 6h31–22h29 | 22h30–6h30 | 6h31–22h29 | 22h30–6h30 | 6h31–22h29 | 22h30–6h30 |
| Mode   | health care costs (Euro) | health care costs (Euro) | health care costs (Euro) |
| pass. cars | 14,615,670 | 4,539,150 | 14,766,975 | 4,391,775 | 12,515,085 | 3,937,860 |
| mopeds | 1,935,525 | 265,275 | 1,906,050 | 259,380 | 1,474,715 | 184,710 |
| motorcycles | 14,806,275 | 1,371,570 | 15,623,715 | 1,436,415 | 12,589,755 | 1,123,980 |
| pedestrians | 4,242,435 | 259,380 | 4,161,870 | 284,925 | 3,983,055 | 275,100 |
| bicycles | 347,805 | 13,755 | 406,755 | 17,685 | 424,440 | 25,545 |

4. A method to improve PTWs safety conditions

Within the study to reduce speed in night hours, the acknowledgement of the entity of such expenditure was associated to the location of the accidents involving PTWs across the whole urban area, which was done utilizing a full featured Geographic Information System (GIS) model. This was not aimed at just creating a map of black spots, but at identifying links (or part of them, as “sub-links”) with the same accidents density. Additional information on PTWs associated to each link or sub-link included indicators as: a) Frequency of accidents with
fatalities (events according to fatalities/km); b) Frequency of accidents with injured individuals (events according to injured riders/km); c) Frequency of accidents (events/km); d) Frequency of fatalities (fatalities/km) and d) Frequency of injured riders (injured riders/km); along with data such as the street name, traffic flows, length of the link, etc.

This allowed to assess whether these links (Figure 1), and the information associated to them, can become elements of priority when planning road safety interventions (which, on the contrary, are usually planned assuming the safety of private cars as major elements of decision). An opportunity to assess the possibility to revise such usual course of safety interventions is given by the recent national decree on road safety inspections (MIT 2012b) which enforces the possibility to calculate a specific indicator, i.e. the Safety Potential ($\sigma$). This indicator allows to draw a priority list of road links for which is of the utmost importance to intervene to improve safety, by assessing the consequent expected reduction of accidents and costs to these associated.

Fig. 1. Road links according to PTWs accidents density.

4.1. The calculation of the Safety Potential $\sigma$

The Safety Potential $\sigma$ (kEuro/km²/year) can be calculated as the difference between ADAC as $\delta_{CA}^m$ (the Average Density of Accident Costs) and BRADAC as $D_{CA}^m$ (the Basis Rate of the Average Density of Accident Costs), i.e. as:

$$\sigma = \delta_{CA}^m - D_{CA}^m =$$

$$= \frac{C_a^A}{L} - \frac{C_a}{L} \cdot 10^{-3}$$

(1)

$\delta_{CA}^m$ is calculated as the ratio between the average yearly cost of accidents $C_a^A$ (kEuro/year) and the length of the considered road section L (km), as:

$$\delta_{CA}^m = \frac{C_a^A}{L}$$

(2)

where $C_a^A$ is the sum of fatalities and injured and the associated costs.

More specifically:

$$C_a^A = \sum_k (N_k \cdot C_k) =$$

$$= N_F \cdot C_F + N_S \cdot C_S + N_M \cdot C_M$$

(3)
with \( N_F \), \( N_S \) and \( N_M \), respectively the yearly amount of fatalities, severely injured and lightly injured, and \( C_F \), \( C_S \) and \( C_M \) (\( \text{k€} \)) respectively the corresponding average costs for fatalities, severely injured and lightly injured.

\[
D_{c,a}^{m} = \frac{(R_{c,a} \cdot 365 \Phi_d)}{10^6}
\]  

(4)

where:

ACR as \( R_{c,a} \) (\( €/1000*\text{veh*km} \)) is the Accident Cost Rate and ADT as \( \Phi_d \) (veh/day) is the Average Daily Traffic (BAST-SÉTRA 2005). More specifically, \( R_{c,a} \) is calculated as:

\[
R_{c,a} = \frac{1000 \cdot C_a}{365 \cdot \Phi_d \cdot L_t}
\]  

(5)

where \( C_a \) is calculated as:

\[
C_a = \sum_j (A_j \cdot C_j^m) = A_{FS} \cdot C_{FS}^m + A_M \cdot C_M^m + A_D \cdot C_D^m
\]  

(6)

with \( A_{FS} \) as the sum of the number of fatal accidents and that of accidents with severe injuries, \( A_M \) as the amount of accidents with minor injuries, \( A_D \) as the amount of accidents with no fatalities/injuries and \( C_j^m \) as the average cost per accident category \( J \); \( t \) is the number of years of the analysis period. Reference values of such parameters are provided by the aforementioned decree.

In the nighttime assessment, \( \Phi_d \) in eqn (4) and eqn (5) was substituted by the Average Nighttime Traffic (\( \text{ANT-\Phi}_n \)), in veh/day, which includes the estimation of nighttime flows on the network from 22h30 to 6h30.

4.2. The Safety Potential for PTWs

A previous study successfully tested the possibility to apply \( \sigma \) for a very small fleet of PTWs (Sgarra et al. 2014), and paved the way for the estimation of \( \sigma \) for the first time at city scale. The most interesting results concern the nighttime situation, due to the criticalities observed in the analysis previously reported in section 2, which allowed to draw a priority list including 150 roads across the whole urban area.

From the first 30 ranked links (table 5) some considerations on the entity of improvements to increase safety for PTWs, especially during nighttimes, arise. The majority of links from which it is possible to save more in term of social costs, on a yearly basis, and thus calls for more urgent road safety interventions for PTWs, are main collector roads and provide connections between collector and arterial roads; therefore interventions aimed at reducing speed may be beneficial to the other motorized modes, as well, given the high traffic flows occurring on such links.

Land use seems to affect the ranked links too: a number of links is located in historic central (Figure 2) and semi-central areas, some of which with premium value built environment, not planned to meet requirements typical of motorized modes.

PTWs high traffic volumes in such areas are due to the local nightlife attractiveness (it is worth reminding that two-wheelers and especially mopeds are the most popular mode for hanging around); on the other, many links are located at mono-functional areas, mostly residential, where especially in nighttimes their function turns into the provision of faster connections, similarly to arterial roads. The link ranked first serves as a case in point: a road connecting two city landmarks (the Coliseum and the Roman Forum) to one of the most important square, Via dei Fori Imperiali is no longer accessible for private cars and PTWs; in 2013 the Municipality acknowledged its role of pedestrian realm (also after some fatal accidents involving cyclists) and turned it into a semi-pedestrianized area accessible by buses, only. Its highest \( \sigma \) value was just one more evidence of its unsuitability as collector road and of its poor safety level for all the modes.

As expected, the calculation of daytime \( \sigma \) highlights higher values than the nighttime ones, due to the higher traffic flows; however, it is not infrequent that for some of the links with a higher amount of daytime accidents (and among these some of those reported in table 5), \( \sigma \) nighttime values are nonetheless higher due to the higher accidents severity in this period.
Table 5. Estimated $\sigma$ for PTWs in Rome, first 30 ranked links.

| Year | Link (streetname)                        | $\sigma$ [KEuro/(Km year)] | Street function | injured/deceased (unit) | $\sigma > 25,000$ |
|------|-----------------------------------------|----------------------------|-----------------|-------------------------|-------------------|
| 2010 | Fori Imperiali*                         | 25,037.9                   | Collector       | 1                       | $\sigma > 25,000$ |
| 2010 | Lungotevere dei Cenci*                  | 23,127.4                   | Main Collector  | 10                      |                   |
| 2010 | Tor Tre Teste A                         | 20,130                     | Collector       | 10                      |                   |
| 2011 | Prenestina C                            | 15,718.6                   | Collector       | 19                      | 24,999 > $\sigma$ |
| 2010 | Ettore Rolli                            | 11,051.8                   | Collector       | 3                       |                   |
| 2010 | Cristoforo Colombo F                    | 10,275.6                   | Main Collector  | 6                       |                   |
| 2010 | Foro Italico**                          | 10,128.2                   | Arterial        | 2                       |                   |
| 2010 | Lungotevere Maresciallo Diaz**          | 9,620.6                    | Main Collector  | 4                       |                   |
| 2011 | Sorbona                                 | 9,310.3                    | Main Collector  | 3                       |                   |
| 2010 | Cilicia**                               | 8,705.6                    | Main Collector  | 12                      |                   |
| 2010 | Cristoforo Colombo A                    | 7,774.7                    | Main Collector  | 5                       |                   |
| 2010 | Marconi A                               | 7,271.4                    | Collector       | 7                       |                   |
| 2010 | Porta Maggiore*                         | 6,724.5                    | Collector       | 3                       |                   |
| 2010 | Corso d'Italia A*                       | 6,548.4                    | Collector       | 2                       |                   |
| 2012 | Porto di Ripa Grande*                   | 5,973.6                    | Main Collector  | 4                       | 9,999 > $\sigma$ |
| 2011 | Flaminia Nuova A                        | 5,725.8                    | Main Collector  | 11                      | > 5,000           |
| 2010 | Tiburtina B                             | 5,647.7                    | Collector       | 3                       |                   |
| 2010 | Lungotevere della Vittoria**            | 5,523                      | Main Collector  | 1                       |                   |
| 2012 | Cristoforo Colombo C                    | 5,387.3                    | Main Collector  | 2                       |                   |
| 2010 | Cristoforo Colombo C                    | 5,327.2                    | Main Collector  | 1                       |                   |
| 2012 | L. in Augusta*                          | 5,263                      | Main Collector  | 8                       |                   |
| 2012 | Teatro di Marcello*                     | 5,132.5                    | Collector       | 2                       |                   |
| 2011 | Cavour*                                 | 5,045.5                    | Main Collector  | 10                      |                   |
| 2012 | Cassia B                                | 4,883.2                    | Main Local      | 9                       |                   |
| 2011 | Lungotevere. Farnesina*                 | 4,754                      | Main Collector  | 1                       |                   |
| 2010 | Bravetta                                | 4,672.3                    | Collector       | 3                       | 4,999 > $\sigma$ |
| 2011 | Casilina D                              | 4,655.1                    | Collector       | 4                       | > 4,000           |
| 2012 | Monti Tiburtini                         | 4,418.4                    | Main Collector  | 1                       |                   |
| 2012 | Marconi B                               | 4,340.7                    | Collector       | 2                       |                   |
| 2011 | Laurentina                              | 4,316                      | Collector       | 2                       |                   |

*central **semicentral
4.3. The estimation of the Safety Potential for events involving other modes

Table 5 reports the top priority links to consider to improve safety, but the list of 150 roads above-mentioned also includes multimodal events. The estimation of $\sigma$, per se, is as a matter of fact easily adaptable to events involving other modes (both non-motorized and motorized ones), provided to have the data and the information needed for its calculation available. Therefore, the possibility to extend the Safety Potential calculation for passenger cars, heavy vehicles or pedestrians has to address the issue of the likely unavailability of such knowledge base of consolidated data to calculate ADAC and BRADAC for the other modes. The lack of such resources can be, then, the actual barrier for the calculation of the Safety Potential. On the contrary, the possibility to calculate $\sigma$ including all the modes and multimodal events might result into a more detailed estimation of the Safety Potential, since it might be based on the total amount of occurring accidents and thus enable to estimate probably higher, but even more realistic $\sigma$ values. As a consequence, the calculation of multimodal Safety Potential could help increase the accuracy of priorities, as it might identify links to intervene to improve safety, resulting from the assessment of the expected reduction of all the accidents (not only those involving just PTWs) and their associated costs.

5. Conclusions

Health care costs due to road accidents are difficult to assess, and in the Italian case regulations can lead to underestimate them. But even so, the awareness of their volume, especially if related to modes not central in the mobility policies, as PTWs, stresses the need to increase even more safety levels and improve the quality of post-crashes responses. The knowledge of the entity of such expenditures could also largely improve accuracy in the analysis of black spots in general and, more specifically, help detect critical road sections and determine, by the calculation of $\sigma$, how much could be saved thanks to appropriate interventions.

The case study of Rome is an evidence of how a regular assessment of $\sigma$ could pave the way for major improvements in the field of safety; prospective applications might involve the possibility to draw up maps of roads classified according to risk levels, useful to monitor PTWs accidents and prevent further occurrences. Such maps, updated in real-time and also available on navigation systems and web portals, can be used to manage infrastructures through a plan of priority interventions to continuously improve current safety levels. The method for calculating $\sigma$ is not only adaptable to events involving other modes, but also easily transferrable to other cities. However, the Safety Potential, as based on accident data regularly collected by the municipalities, stresses the need to have homogeneous parameters to assess the costs for road accidents and especially the health care costs, at least at European level. The analysis of scientific literature highlighted very different approaches in considering which “items” have to be considered in the list of health care costs, and the poor accuracy of those too general, which leads to a general underestimation of the expenditure. The next research question open to decision-makers and scientists, for a shared procedure for calculating these costs, is then two-pronged: on the one hand, it is necessary to determine, under the medical point of view, the appropriate care treatments and the corresponding costs on national basis. This is not an easy task as injuries and post-crashes responses to medical treatment and rehabilitation vary (per severity of injuries, mode involved, age and vulnerability of victims, etc.), but the huge practice in this field could provide a sound basis for a health care costs registry at European level. On the other hand, nothing of the above can be enforced without a strong political willingness to promote common, equal opportunities to provide appropriate rehabilitation procedures for all the road safety victims across Europe. This requires supranational regulatory tools, specific funding and a stronger awareness of the entity of these costs. The calculation of $\sigma$, by assessing the consequent expected reduction of accidents and costs to these associated, stresses how such costs are per se not affordable for a community. It is not surprising, then, that thus far the underestimation of such costs is the only way to cope with their unaffordability. To conclude, the issue whether the awareness of such costs can be used as leverage for more mindful behaviors among the riders is one more open research question. It is difficult to assess whether the health care yearly theoretical cost per inhabitant of about 7 Euros calculated for the Roman riders can be a convincing argument. A survey run in Rome in 2007 aimed at profiling typical local two-wheeler users was decisive to determine that costs in general were not so relevant: according to drivers and riders responses, the annual maintenance costs for two-wheelers were higher than those for cars (respectively about 0.31 and 0.22 €*km) (IAC, 2008), but worth to be “paid” thanks to the higher personal convenience and freedom provided by this mode. In light
of these responses, probably 7 Euros can be considered a minor cost to access privilege and independence, but this is one more evidence that more in the field of safety awareness among the riders community can be done.

References

ATAC, 2005. Rapporto sulla mobilità 2005. www.atac.roma.it.

Baldock, M.R.J. and McLean, A.J., 2005. The economic cost and impact of the road toll on South Australia. Centre for Automotive Safety Research, Adelaide. http://casr.adelaide.edu.au/publications/list/?id=525.

BAST-SETRA, 2005. Network Safety Management NSM – Report. www.bast.de/cn_005/nn_82230/EN/e-Aufgaben/e-abteilung-v/e-referat-v1/e-sicherheitsanalyse/e-sicherheitsanalyse.html.

Bastida, J.L. et al., 2004. The Economic Costs of Traffic Accidents in Spain. Journal of Trauma, 56(4), 883–888.

Chini, F. and Farchi, S., 2011. Costi Sanitari degli Incidenti Stradali nella Regione Lazio. Presentation at the Workshop “Buone pratiche sulla sorveglianza e prevenzione incidenti domestici e stradali”, Rome 5.12. 2011. www.asplazio.it/asp_online/prev_for_doc/files/ppa/workshop_5dicembre2011/costi-sanitari-incidenti-stradali_Chini.pdf.

DfT – Department for Transport. 2013. Reported Road Casualties in Great Britain: 2012 Annual Report. www.gov.uk/government/publications/road-accidents-and-safety-statistics-guidance.

Elvik, R., 1995. An analysis of official economic valuations of traffic accident fatalities in 20 motorized countries. Accident Analysis and Prevention, 27(2), 237–247.

ERSO, 2012. Traffic Safety Basic Facts 2012. Motorcycles and Mopeds. http://ec.europa.eu/transport/road_safety/pdf/statistics/dacota/bfs2012-dacota-niua-motomoped.pdf.

Garcìa Altés, A. and Pérez, K., 2004. The Economic Cost of Traffic Accidents in Spain. Journal of Trauma, 56(4), 883–888.

Hakkert, S. and Wesemann, P. (ed.), 2005. The use of efficiency assessment tools: solutions to barriers. ROSEBUD report. R-2005-2. SWOV, Leidschendam.

IAC – Automobil Club d’Italia ACI. 2008. L’auto libertà responsabile. http://www.aci.it.

Jeffrey, S.K.E., 2010. Epidemiology, cost and prevention of road traffic crash injuries in Strathclyde, University of Glasgow, Glasgow, http://theses.gla.ac.uk/1448/.

Lattarulo, P., 2012. I Costi Sociali degli Incidenti Stradali. Presentation at the Conference “Incidenti stradali in Toscana: i dati, le azioni di prevenzione, le azioni di controllo”, Florence 27.11.2012. www.irpet.it/storage/eventoallegato/1110_costi%20incidenti%20stradali_Latta_sett12.pdf.

Malchose, D. and Vachal, K., 2010. Medical and Economic Cost of North Dakota Motor Vehicle Crashes. Rural Transportation Safety and Security Center Upper Great Plains Transportation Institute, North Dakota State University, Fargo. www.ugpti.org/pubs/pdf/DP225.pdf.

Meerding, W.J. and Toet, H., 2002. A Surveillance Based Assessment of Medical Cost of Injury in Europe: Phase 1. Department of Public Health, Erasmus University, Rotterdam.

MIT – Ministero delle Infrastrutture e dei Trasporti, 2012a. Studio di valutazione dei costi sociali dell’incidentalità stradale – Anno 2011. http://www.mit.gov.it/mit/mop_all.php?p_id=12919.

MIT – Ministero delle Infrastrutture e dei Trasporti, 2012b. D.M. 2.5.2012. Linee Guida per la gestione della sicurezza delle infrastrutture stradali, Suplemento ordinario n. 182 alla Gazzetta Ufficiale, n. 209, 7.9.2012.

MTNZ – Ministry of Transport of New Zealand, Financial, Economic and Statistical Analysis Team, 2013. Social Cost of road crashes and injuries, 2012. www.transport.govt.nz/research/roadcrashstatistics/thesocialcostofroadcrashesandinjuries/.

Musso, A., et al., 2010. A research agenda for public policy towards motorized two-wheelers in urban transport, in Proceedings of TRB 89th Annual Meeting, Washington D.C.

Naumann, R.B. et al., 2010. Incidence and Total Lifetime Costs of Motor Vehicle–Related Fatal and Nonfatal Injury by Road User Type, United States 2005. Traffic Injury Prevention, n. 11(4), 353–60.

Risbey, T. et al., 2010. Cost of Road Crashes in Australia. Proceedings of the Australasian Transport Research Forum 2010, Canberra. www.atrf.info/papers/2010/2010_Risbey_Cregan_deSilva.pdf.

Rome Municipality, 2009. Piano Strategico della Mobilità Sostenibile 2009. www.psms.roma.it/.

Sgarra, V. et al., 2014. An application of ITS devices for powered two-wheelers safety analysis: the Rome case study. Advances in Transportation Studies, 33(1), 85–96.

Soriano Somovilla, I., 2010. Los accidentes de tráfico y su incidencia en el sistema de la seguridad social (2000–2009). Ministerio de Empleo y Seguridad Social, Madrid.

Surace, M. et al., 2010. A comparative study of the development of motorcycling road safety in Barcelona, London, Paris and Rome. eSUM Report 2.1. 2010. http://www.eSUM.eu.

WHO – World Health Organization, 2010. Global Report for the Decade of Action for Road Safety 2011–2020. www.who.int/roadsafety/decade_of_action/plan/en/.

WHO – World Health Organization, 2013. Global Status Report on Road Safety 2013– Supporting a decade of action. Online http://www.who.int/prevention/road_safety_status/2013/en/.