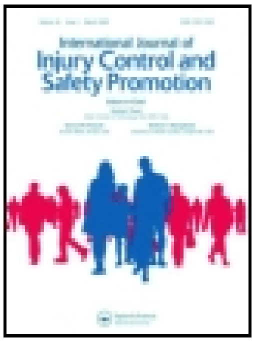


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# Geographic distribution of suicide and railway suicide in Belgium, 2008–2013: a principal component analysis

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This study investigated the geographic distribution of suicide and railway suicide in Belgium over 2008–2013 on local (i.e., district or *arrondissement*) level. There were differences in the regional distribution of suicide and railway suicides in Belgium over the study period. Principal component analysis identified three groups of correlations among population variables and socio-economic indicators, such as population density, unemployment, and age group distribution, on two components that helped explaining the variance of railway suicide at a local (*arrondissement*) level. This information is of particular importance to prevent suicides in high-risk areas on the Belgian railway network.

**Keywords:** Belgium; geographic distribution; hotspots; principal component analysis; railway; suicide

## Introduction

Suicide on the railway network is a serious public health and safety problem in many countries (Ladwig, Ruf, Baumert, & Erazo, 2009). In 2012, 2997 suicide cases have been recorded on railway networks within the European Union (EU), accounting for 70% of railway fatalities and representing 8% of all suicides in the EU countries (European Railway Agency, 2014). There are differences in the prevalence of suicide on the railway among countries. Studies in Western Europe show that railway suicide accounts for 5%–11.5% of all suicide cases (Andriessen & Krysinska, 2012; Baumert, Erazo, & Ladwig, 2005; Rådbo, Svedung, & Anderson, 2005; van Houwelingen, Kerkhof, & Beersma, 2010). A lower prevalence of railways suicide, between 1.5% and 2.2%, has been reported in North America (Kposowa & McElvain, 2006) and Australia (De Leo & Krysinska, 2008). Despite its relative statistical rarity, rail suicide is a highly lethal method of self-injury with up to 94% of attempts leading to death (Krysinska & De Leo, 2008; Ladwig et al., 2009).

There appears to be particular patterns of individual and environmental risk factors related to the choice of rail suicide as a method of self-inflicted injury. Individual risk factors include male sex (Kposowa & McElvain, 2006; Palanco, Lucas, Rojas, & Martinez, 1999; Rådbo & Andresson, 2012), younger age (20–40 years) (De Leo & Krysinska, 2008), psychopathology, especially affective disorders and schizophrenia, and a history of psychiatric hospitalization (Abbot et al., 2003; Berman, Sundararaman, Price, & Au, 2014; Lukaschek et al., 2014b; van Houwelingen & Kerkhof, 2008). Also imitation and contagion, via mass media (e.g., Koburger et al., 2015; Ladwig, Kunrath, Lukaschek, & Baumert, 2012; Niederkrotenthaler & Sonneck, 2007) and/or personal contact with someone who has attempted or died by suicide on the railway track (O'Donnell, Arthur, & Farmer, 1994), may play a role in the choice of this suicide method.

Although the results of the studies on the environmental factors are not consistent, due to the differences in the studied populations, characteristics of the railway systems, and operationalization of indicators (Too, Milner, Buheja, & McClure, 2014), several socio-environmental variables have been found to relate to the incidence of railway suicide. These include availability, accessibility and familiarity with the railway and trains (e.g., Too et al., 2014), circadian, weekly and seasonal effects (e.g., Lukaschek, Baumert, Erazo, & Ladwig, 2014a; van Houwelingen & Beersma, 2001), proximity of mental health institutions (e.g., Debbaut, Krysinska, & Andriessen, 2014), suicide rates in the general population (e.g., van Houwelingen et al., 2010), and socio-economic and demographic composition of the population (e.g., Niederkrotenthaler et al., 2012).

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Belgium is a Western European country with a relatively high suicide rate and differences in the incidence of suicide among its three geographical and administrative regions: the northern Flemish region, the southern Walloon region, and the Capital region of Brussels. In 2011 the suicide rate in Belgium was 19.0 per 100,000 with 2084 self-inflicted deaths recorded, and the regional suicide rates for Flanders, Brussels, and Wallonia were 18.1 per 100,000, 13.0 per 100,000, and 22.6 per 100,000, respectively (Statistics Belgium, 2015). There were 1092 railway suicides in Belgium over the period of 1998−2009 and 557 suicide attempts over 2003−2009 with a railway suicide rate of 1.03 per 100,000 in 2004 (Andriessen & Krysinska, 2012). The railway suicide fatality rate of 54% reported in Belgium (Andriessen & Krysinska, 2012) seems relatively low in comparison with other European railway networks, e.g., 94% in Germany (Schmidtke, 1994) and 91% in the Netherlands (Van Houwelingen et al., 2010). This low rate could be related to the reporting of incidents without physical contact with the train, e.g., the person was rescued before being hit by the train as 'suicide attempts' in the official railway statistics (Infrabel, 2014).

A study on the epidemiology of rail suicide in Belgium (Andriessen & Krysinska, 2012) found differences in the regional distribution of railway suicides. The majority of fatalities were recorded in Flanders (69%), followed by Wallonia (23%), and Brussels (8%), which seemed to reflect the regional distribution of the numbers of suicides in the country and the population size of the regions; however, not the regional distribution of railway length (Andriessen & Krysinska, 2012). An analysis of suicide hotspots, i.e., areas of the railway network with an elevated incidence of suicide, found that the majority of hotspots (76%) were located in Flanders (Debbaut et al., 2014).

This study aims to further investigate the geographic distribution of rail suicide and total suicide in Belgium on a local (i.e., district or *arrondissement*) level and to look at a number of population variables and socio-economic indicators that may be related to the incidence of rail and total suicide on the *arrondissement*-level. The variables of interest in this study are population density, age composition, labour force, and average income. International studies on spatial distribution have reported significant variations in occurrence of suicide related to area-based associations of suicide with demographic and socio-economic indicators (Chang et al., 2012; Middleton, Sterne, & Gunnell, 2008; Pridemore & Spivak, 2003; Rehkopf & Buka, 2006). For example, Chang et al. (2011) found an association between suicide rates in Taiwan on the district level and socio-economic characteristics of the area, such as population density, median household income, proportion of lone-parent households, and educational level. Middleton et al. (2004) reported a positive association between measures of socio-economic deprivation and social fragmentation, and suicide rates in small areas in the UK (i.e., electoral wards). A negative correlation between suicide mortality and population density has also been reported in the study of community-level correlates of suicide mortality in the Flemish region of Belgium (Hooghe & Vanhoutte, 2011). Other studies indicated higher suicide rates in the French-speaking Wallonia than in Dutch-speaking Flanders, a phenomenon which might be related to differences in availability of suicide methods, socio-economic factors, and cultural differences (Moens, Loysch, & van de Voorde, 1988; Reynders et al., 2011).

Although a number of studies looked at the spatial patterning of suicide by different methods, such as hanging, solids/liquids/gas poisoning, jumping, firearms, and drowning (Chang et al., 2011; Chang et al., 2012; Moens et al., 1988), to the best of our knowledge no study to-date has applied a spatial analysis to analyse the geographic distribution of railway suicide.

## Method

### *Area of study and level of analysis*

The study area is Belgium (Figure 1), a federal state with the total population on 1 January 2013 of 11,099,554 inhabitants and covering a territory of 30,528 km (Table 1). Both the Flemish and the Walloon region consist of five provinces: Antwerp, East Flanders, Flemish Brabant, Limburg, and West Flanders; and Hainaut, Liège, Luxembourg, Namur, and Walloon Brabant. The level of analysis in this study is an *arrondissement*, i.e., a geographical/administrative area, also called a 'district', consisting of a few municipalities but smaller than a province. This level of analysis was chosen because the study investigates local variations in suicide mortality, and the *arrondissement* is the smallest geographical area for which sufficient data are available. There are 43 *arrondissements* in Belgium.

Although the population of Brussel's city centre is relatively poor, surrounding provinces, such as Walloon Brabant and Flemish Brabant are among the richer parts of Belgium. There is an urban continuum in the centre of Wallonia, which is the poorest part of the region (due to the old industrial inheritance), linking big cities such as Liege, Namur, Charleroi, Mons, and Tournai. The geography of the rail network reflects the repartition of Belgian population and activities: the network is denser in the northern part of the country and around Brussels, while the rail infrastructure in Wallonia is relatively poor. The main rail link in Wallonia is the west–east urban continuum, linking Mons, Charleroi, Namur, and Liege.

### *Material*

#### *Suicide and population data*

The data on suicide in Belgium (total suicide per inhabitant and total suicide per km$^2$) on the *arrondissement*-level in


Figure 1. Belgium: regions, provinces, *arrondissements*, main cities, and railway network.

2008 were obtained from the Belgian Institute of Statistics (Statistics Belgium, 2015). Data on rail suicide per inhabitant and rail suicide per km$^2$ over 2008–2013 was provided by the Belgian Manager of the Rail Infrastructure (Infrabel, 2014). The Infrabel data included information on the location of the suicide and the incidents were grouped on the *arrondissement*-level for the purpose of this study. Data on population density (municipality population per km$^2$), share of young people (people younger than 18 years/total population; %), share of active population or labour force (people aged 18–65 years/total population; %), and share of the elderly (people over 65 years/total population; %) in 2012 was obtained from the Belgian Institute of Statistics (Statistics Belgium, 2015).

Table 1. Regional distribution of railway suicide in Flanders, Wallonia, and Brussels.

| Region | Suicide 2008 (*N*) | Railway suicide 2008−2013 (*N*) | Length of railway | Population 2013 | Population density | Area km$^2$ | Gross domestic product (GDP) per capita 2011 |
|---|---|---|---|---|---|---|---|
| Flanders | 1058 | 338 | 1765 km (49.3%) | 6,381,859 (57.5%) | 472.0 per km$^2$ | 13,521 km$^2$ (44.3%) | 30,200 euro |
| Wallonia | 714 | 167 | 1641.5 km (45.9%) | 3,563,060 (32.1%) | 211.5 per km$^2$ | 16,845 km$^2$ (55.2%) | 24,600 euro |
| Brussels | 196 | 58 | 171.5 km (4.8%) | 1,154,635 (10.4%) | 7127.4 per km$^2$ | 162 km$^2$ (0.5%) | 62,000 euro* |
| Belgium total | 1976 | 563 | 3578 km (100%) | 11,099,554 (100%) | 363.6 per km$^2$ | 30,528 km$^2$ | 33,600 euro |

Source: Infrabel (2014); Rijksdienst voor Sociale Zekerheid (2015); Statistics Belgium (2015). *The GPD in Brussels may be artificially inflated as approximately 50% of jobs are occupied by commuters from Wallonia and Flanders and approximately 16% of residents of Brussels work in Flanders or Wallonia.

*Social and economic measures*

Socio-economic data on the *arrondissement*-level for 2012 were obtained from the National Social Security Office (Rijksdienst voor Sociale Zekerheid, 2015). The following five socio-economic characteristics were included: activity rate (share of the population that is on the labour market, i.e., workers plus unemployed/total population; %), self-employment rate (self-employment/active population; %), employment rate (workers/active population; %), unemployment rate (unemployed/active population; %), and average household income.

### *Analysis*

Principal component analysis (PCA) was used to process the data and to identify both the geography of railway suicides and the explanatory factors for these particular locations. All data used in this study were analysed on the level of *arrondissement*. Departing from the initial variables (see Material), this statistical approach aims at identifying the coherent information that is contained in it. The PCA works as if each initial variable was a dimension of the initial cloud of information, i.e., the departing matrix. Based on correlation factors between initial variables and on the variance of the observations (in this analysis, the *arrondissements*) on these variables, the PCA identifies the statistic links between the initial variables, highlights the main coherent information, and detects strong patterns contained in the initial variables.

In the next step, PCA builds new synthetic variables, the components, in order to maximize the coherent information they contain (based on the variance) and to be independent from each other. There is a hierarchical classification: the first component will gather more information than the second, the second than the third, etc. Correlations coefficients are calculated between initial variables and new components, these are the saturation levels**.** The saturations of initial variables on the components are useful for understanding the meaning of these new synthetic variables. These saturation values may be analysed as if they were correlation factors between the initial variables and the new components. It may vary from −1 to 1. A positive saturation value on one component means that the variable is positively correlated with the component. The projection of the saturations of components 1 and 2 on the same figure allows identifying groups of initial variables that have similar correlations with the components.

Finally, the initial observations (in this analysis, the *arrondissements*) are positioned on the new components, based on their values on the initial variable. These are the scores of the observations on the components. The calculation of the scores is based on a multivariate correlation between the initial situation of observations regarding the departing variables and their position on the new components. Scores of observations on the component illustrate the situation and oppositions of observations regarding these components. Observations with positive scores have a value higher than average on variables that are also positively correlated with the component and below the average on variables that are negatively correlated with the component.

The analysis was conducted using R statistical freeware (R Core Team, 2012) and the maps were built using QGIS Geographic Information System freeware (QGIS Development Team, 2014).

## Results

### *Descriptive results*

The suicide rate per 1000 inhabitants in Belgium was above the average in the north-western part of the country and in the west–east urban continuum of Wallonia (Figure 2). The geographic distribution of railway suicide was different. The density of rail suicide per km$^2$ was higher in urban areas (Brussels, Gent, Antwerp *arrondissements*, and their suburbs[1] as well as Liège, Charleroi, and Namur) (Figure 3), with a concentration in the more densely populated northern part of the country and around Brussels and Antwerp. The geographic distribution of rail suicides per 1000 inhabitants (Figure 4) shows an overrepresentation of rail suicides in suburban areas. Rail suicide is less frequent in central cities and in the rural parts of Belgium. For both indicators, there is an overrepresentation of railway suicides in the north-western part of the country. The share of railway suicides (rail suicide/total suicide) is higher in city suburbs and in the northern part of the country in general (Figure 5).

### *PCA analysis*

As a first step, a correlation matrix was generated (Table 2). Rail suicide per inhabitant was significantly positively correlated with wealth-related variables, i.e., employment rate, activity rate, and average wage, as well as share of elderly people, and negatively correlated with the share of young people, unemployment rate, and population density. Total suicide per inhabitant was positively correlated with the unemployment rate and negatively correlated with average income and population density.

The PCA resulted in the building of new synthetic variables, i.e., the components. The first component gathered 58% of total information (the variance contained in the initial cloud of information), and the second component represented 18% of total information. In accordance with Kaiser's criterion (drop component with eigenvalue below 1.0), other components were of less importance. Consequently, only the first two components were analysed. There were three groups of correlations (Figure 6).

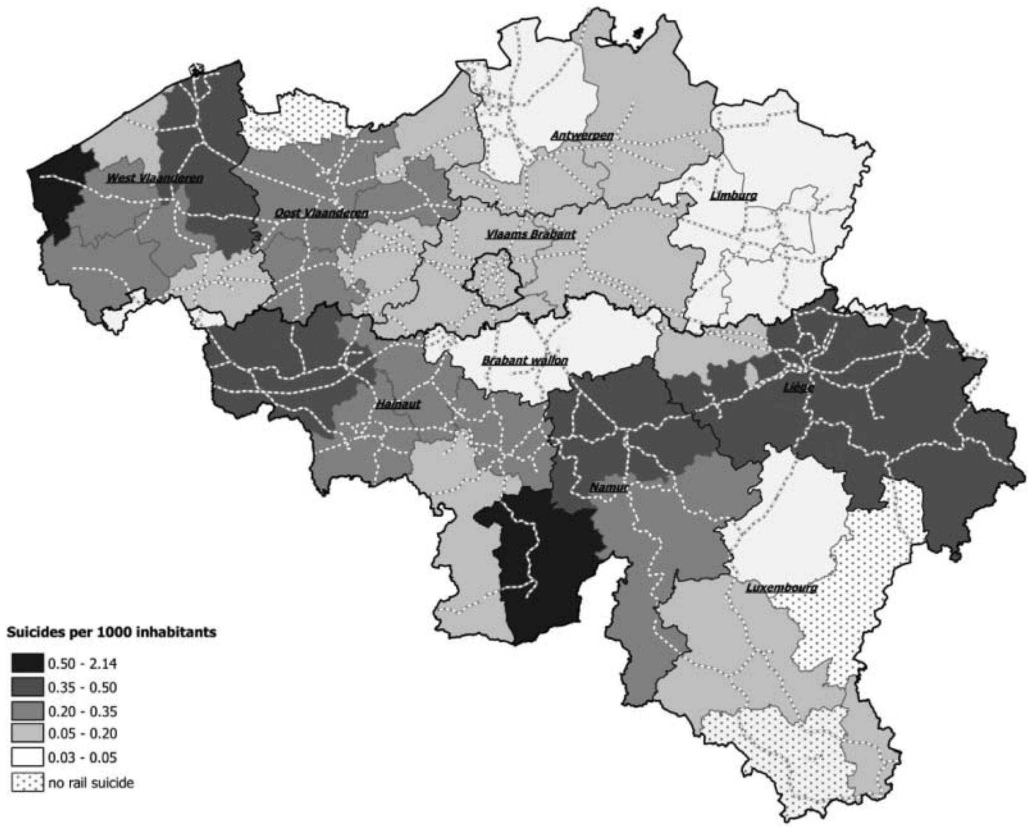


Figure 2. Suicide per 1000 inhabitants, Belgium, *arrondissement*-level (2008).

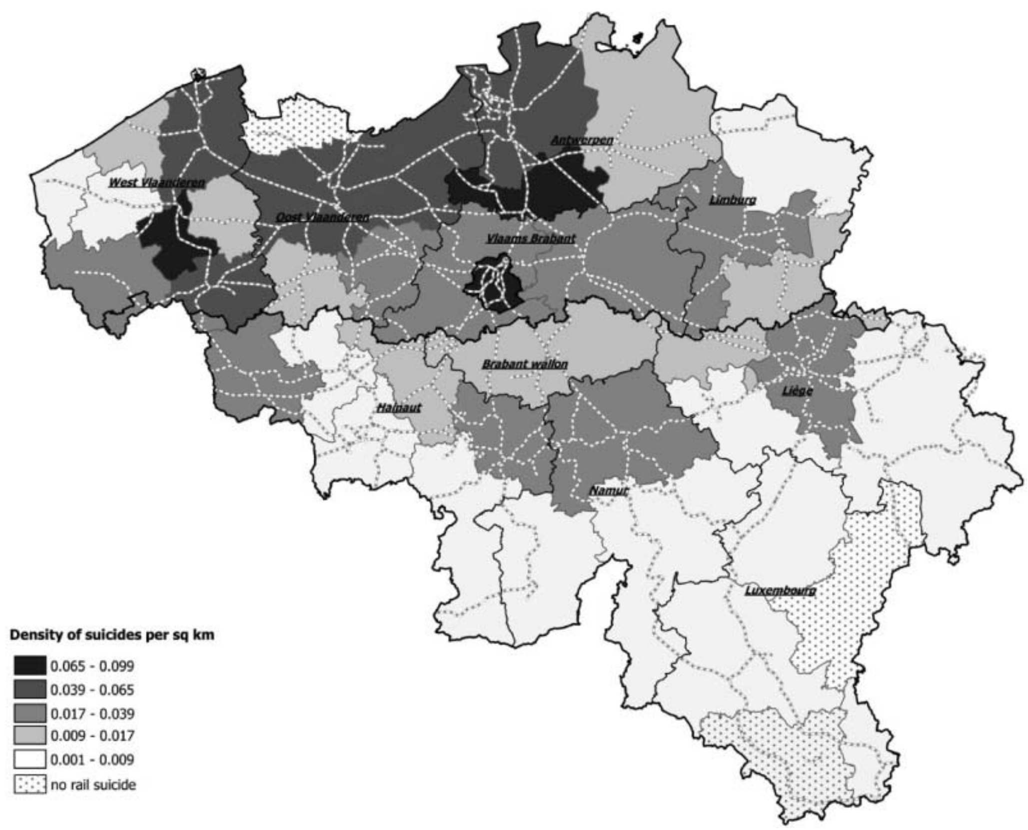


Figure 3. Density of rail suicide per km$^2$, Belgium, *arrondissement*-level (2008–2013).

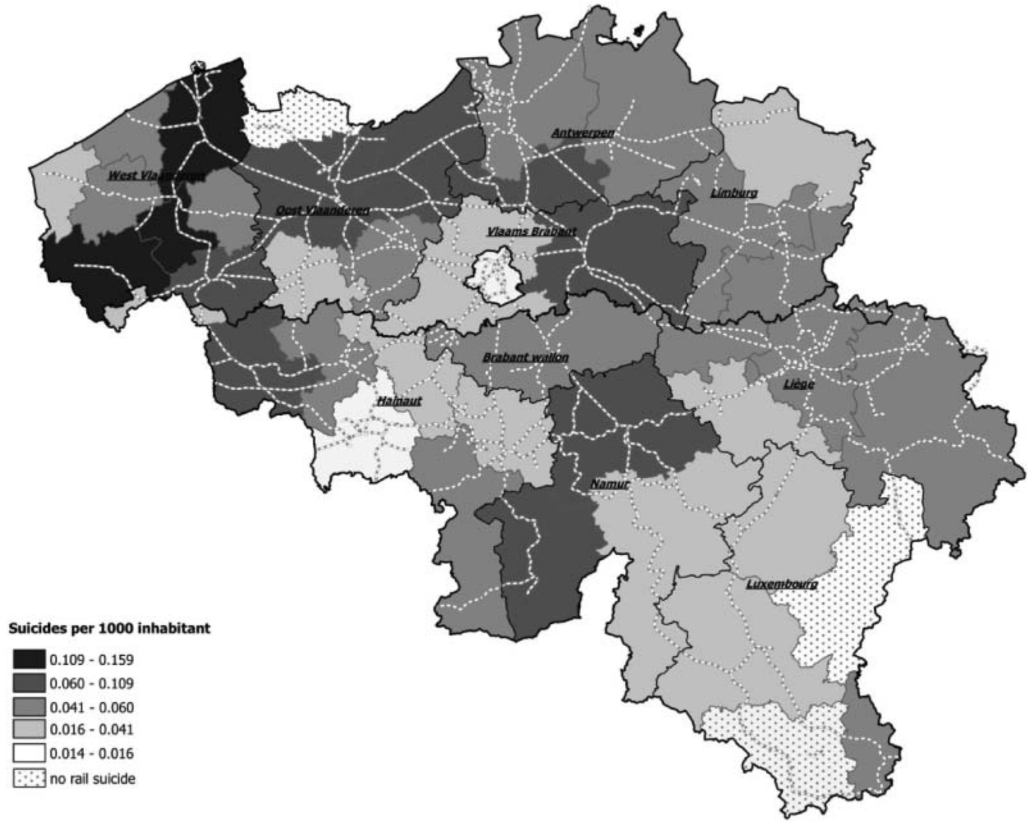


Figure 4. Rail suicide per 1000 inhabitants, Belgium, *arrondissement*-level (2008–2013).

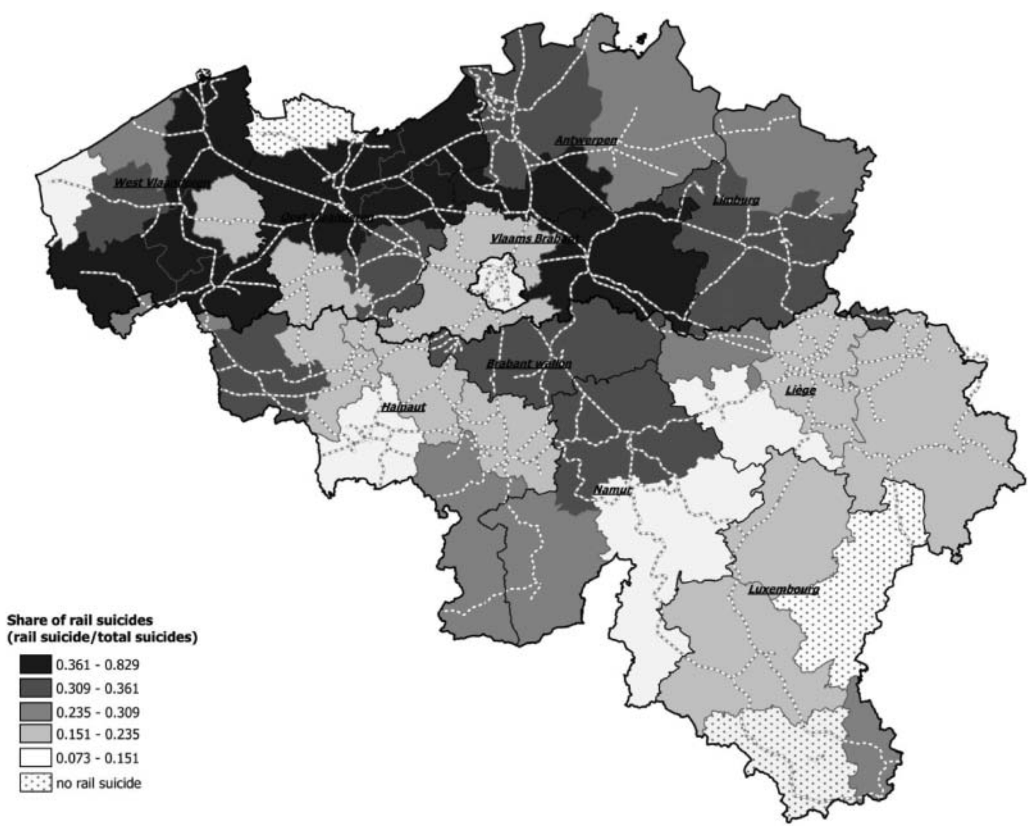


Figure 5. Share of rail suicide (rail suicide/total suicides), Belgium, *arrondissement*-level (2008–2013).

Table 2. Correlation matrix.

| | Activity rate | Employment rate | Unemployment rate | Self-employment rate | Share of the elderly (65+) | Share of active people (18−65) | Share of young people (<18 years) | Population density | Average wage | Total suicide per inhabitant | Total suicide per km$^2$ | Rail suicide per inhabitant | Rail suicide per km$^2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Activity rate | 1.00 | | | | | | | | | | | | |
| Employment rate | 0.96 | 1.00 | | | | | | | | | | | |
| Unemployment rate | −0.88 | −0.98 | 1.00 | | | | | | | | | | |
| Self-employment rate | 0.50 | 0.60 | −0.65 | 1.00 | | | | | | | | | |
| Share of the elderly (65+) | 0.60 | 0.65 | −0.66 | 0.43 | 1.00 | | | | | | | | |
| Share of active people (18−65) | −0.49 | −0.50 | 0.47 | −0.43 | −0.84 | 1.00 | | | | | | | |
| Share of young people (<18 years) | −0.53 | −0.62 | 0.65 | −0.32 | −0.88 | 0.49 | 1.00 | | | | | | |
| Population density | −0.71 | −0.63 | 0.53 | 0.00 | −0.61 | 0.50 | 0.55 | 1.00 | | | | | |
| Average wage | 0.63 | 0.72 | −0.76 | 0.54 | 0.31 | −0.26 | −0.27 | −0.29 | 1.00 | | | | |
| Total suicide per inhabitant | −0.03 | −0.18 | 0.30 | −0.21 | 0.13 | −0.14 | −0.09 | −0.20 | −0.39 | 1.00 | | | |
| Total suicide per km$^2$ | −0.72 | −0.65 | 0.56 | −0.02 | −0.61 | 0.51 | 0.55 | 0.99 | −0.32 | −0.15 | 1.00 | | |
| Rail suicide per inhabitant | 0.67 | 0.64 | −0.58 | 0.32 | 0.52 | −0.37 | −0.51 | −0.45 | 0.36 | 0.18 | −0.45 | 1.00 | |
| Rail suicide per km$^2$ | −0.35 | −0.28 | 0.20 | 0.16 | −0.27 | 0.24 | 0.24 | 0.78 | −0.04 | −0.23 | 0.78 | 0.08 | 1.00 |

Note: Linear correlation coefficient, significance level 1% = 0.39, 5% = 0.30.

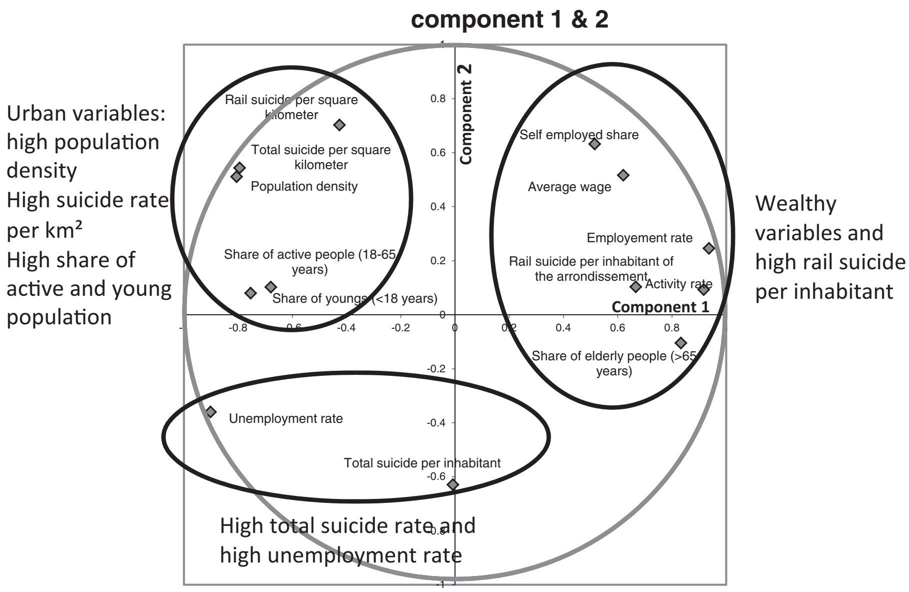


Figure 6. Saturations of variables on components 1 and 2.

(1) Positive correlation on component 1: variables related to the wealth and to the share of rail suicide per inhabitant.
(2) Negative correlation on component 2: high total suicide rate and high employment level.
(3) Negative correlation on component 1 and positive correlation on component 2: variables related to the urban form of *arrondissements*: population density, share of young and active people, and suicide density.

The second major result of PCA analysis is the scores of the observations, i.e., the position of the observations on the new synthetic variables. Here, observations were the Belgian *arrondissements*. On component 1 (Figure 7), there was an opposition between urban *arrondissements*, with negative scores on component 1, which were poorer (higher unemployment rate, lower wages) and younger (higher share of young and active people), and non-urban *arrondissements*, with positive scores on component 1, that were older and richer. In urban *arrondissements*, there

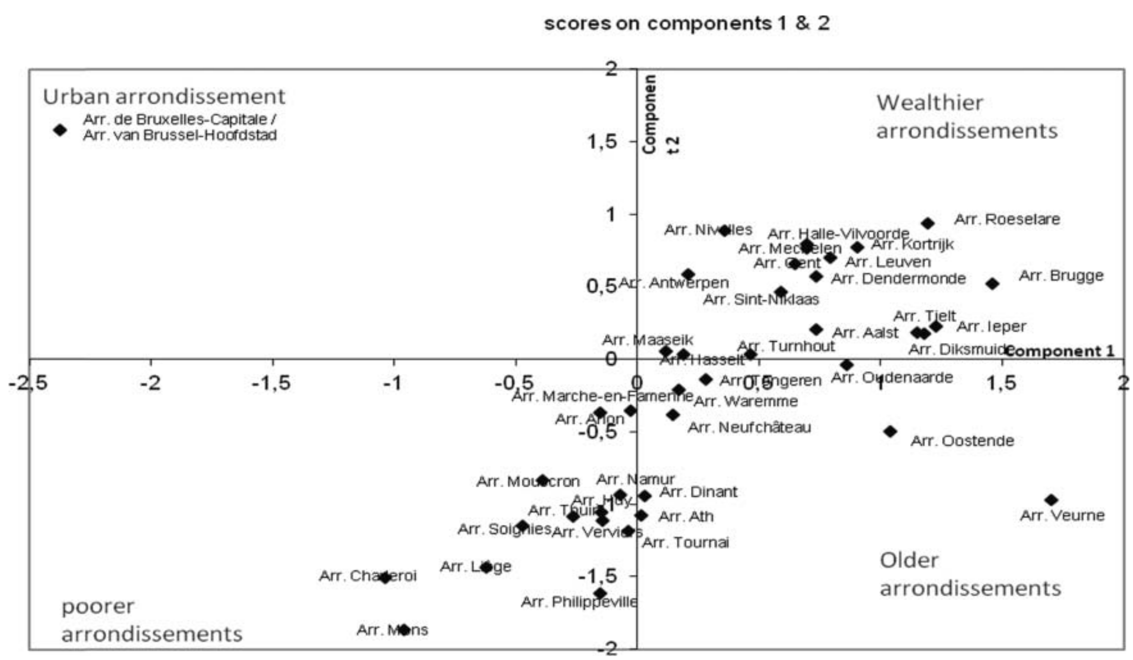


Figure 7. Scores of observations on components 1 and 2.

were more suicides per $km^2$ but rail suicides were underrepresented. Rail suicides were overrepresented in non-urban *arrondissements*. There was an opposition on component 2 between the rich and the poor *arrondissements*. In poor *arrondissements*, with negative scores on components 1 and 2, suicide rate was higher but rail suicide was under the national average; in richer *arrondissements* with positive scores on both components, suicide rate was lower but rail suicide was over the national average.

The scores of *arrondissements* on components 1 and 2 have been mapped for a clearer view (Figures 8 and 9). Geographically, these distributions of suicides in general and of rail suicides in particular differ across areas. South of Wallonia, rail suicide ratio is low and suicides in general are in the average or over average. These are rural places, where population and rail density are low, so rail suicides are rare and underrepresented. However, there were some poor areas, such as the south-west of Wallonia, where total suicide rate was high. In urban Wallonia, between Mons and Liège, suicide rate was high and the rail suicide rate too, due to the poverty of the area.

Yet, the ratio of rail suicide per inhabitant was low in urban *arrondissements*, because these are urban spaces, where the access to rail tracks may be complicated. In Brussels (and to a lesser extent, Gent and Antwerp) rail suicide per inhabitant was under the national average, even if these were numerous, because of the densely populated urban space. In suburban spaces, around Brussels, Gent, and Antwerp, suicide rates were not necessarily high, but the ratio of rail suicide was very high. In north-west Flanders, both total suicide rate and rail suicide rate were high and the ratio of rail suicide was high too. It may be a consequence of the age structure (more elderly people) and of the employment structure (more self-employed people).

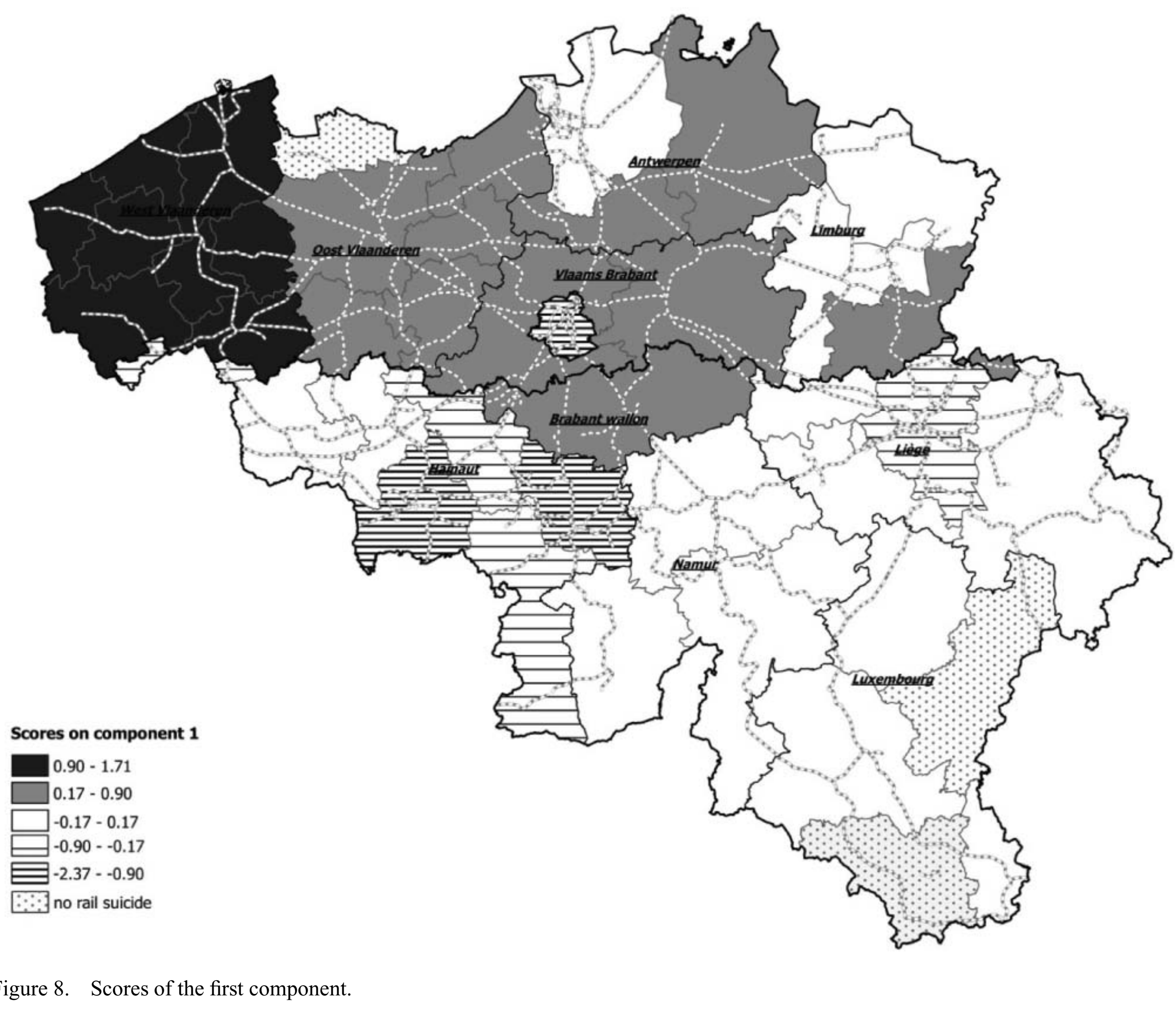


Figure 8. Scores of the first component.

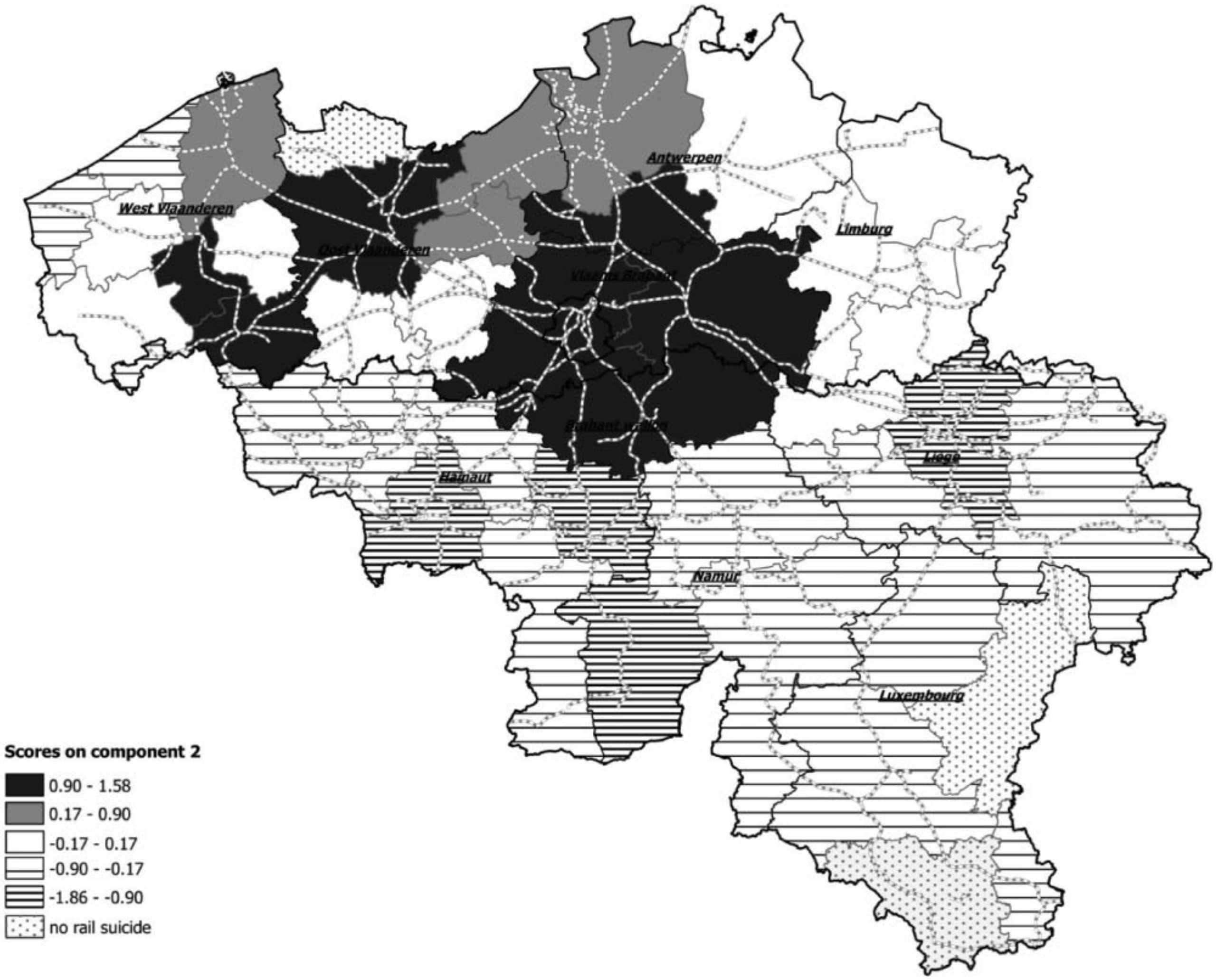


Figure 9. Scores of the second component.

**Discussion**

This study found that there are differences in the geographical distribution of rail suicide and general suicide in Belgium on the *arrondissement*-level. While the general suicide rate was above the average in the north-western part of the country and in the west–east urban continuum of Wallonia, the density of railway suicide was higher in the more densely populated northern part of Belgium, Brussels and major towns in Flanders, and in Wallonia. The share of railway suicides, i.e., rail suicide/total suicide, was the highest in the northern part of the country in general. Rail suicides are numerous in urban areas, but the ratio of rail suicide per inhabitant is higher in suburban areas. In rural area, the number and the ratio of rail suicide are low. Earlier international studies reported on associations between general suicide rates and the rates of rail suicide. A study on underground train suicides in 17 major cities worldwide found no correlation between national and rail suicide rates (Lester, 1995). A study on train suicides in Germany found a negative association (Baumert et al., 2005) and an analysis of train suicides in the Netherlands (van Houwelingen et al., 2010) reported that the incidence of train suicides paralleled that of general population suicides. The two studies from Germany and the Netherlands clearly show that there are differences on the country level, which reflect on the population structure and density of the respective country, thereby underlining the results of this study on a larger scale.

Similar to results of this study, an analysis of the geographical patterns of suicide methods in Belgium over 1962–1972 and 1978–1981 did not find a significant correlation between all method-specific rates and the total suicide rate across the districts (Moens et al., 1988). There was a strong significant positive correlation for hanging, and (in men) for firearms and explosives, however, the correlations for other specific methods were either weak or not significant (suicide by jumping in front of a moving object, including a train, was not included in the analysis). Contrary of the results of this study, a further analysis by Moens and colleagues (1988) did not find a particular geographical distribution of train suicides on the district level in Belgium over 1962−1972 and 1978−1981.

Regarding the association between demographic and socio-economic variables and the incidence of general and rail suicide on the *arrondissement*-level, the PCA showed a positive correlation between rail suicide per inhabitant, share of the elderly and wealth-related variables, i.e., employment rate, share of self-employed, average wage, and activity rate. Lack of studies on socio-demographic determinants of railway suicide calls for caution in discussing the reported results. To the best of our knowledge, the only study to-date which looked at the socio-economic status of the population living in a neighbourhood of subway stations (in Vienna) and railway suicides and suicide attempts (Niederkrotenthaler et al., 2012) found no association between these two variables. The PCA also showed a correlation between total suicide per inhabitant and unemployment rate, reflecting a result frequently reported in cross-sectional and longitudinal studies (Platt, 2011). The third group of PCA correlations indicated a positive association between total suicide per $km^2$, high population density, and a high share of active and young population (i.e., variables related to the urban form of *arrondissements*). Based on these results it can be concluded that railway suicides are more prominent in wealthy areas, with more elderly people, and less prominent in areas with younger population, more unemployment, and higher population density. The finding that rail suicides are more prominent in wealthy areas than poorer regions may partly be related to lower rail density in poorer *arrondissements*.

An analysis of socio-demographic correlates of suicide rates by all methods in Belgium found that population density and ethnicity (i.e., Flemish versus Wallonian) were significantly associated with the suicide rate on the level of provinces, while unemployment, divorce, marriage, and birth rates were significant on the level of the whole country (Andriessen, Krysinska, & Lester, 2015). The disparity between social and economic correlates of suicide rates in Belgium on the different level of analysis, i.e., country, province, *arrondisement*, may reflect Rehkopf's and Buka's (2005) observation that some contextual processes related to social cohesion or networks might work differently on smaller levels of aggregation.

This study has a number of limitations. Results of aggregated data analysis cannot support suicide risk assessment and identification of at risk individuals (Denney, Wadsworth, Rogers, & Pampel, 2015). The study focused on the geographic distribution of suicide on the railway network only and it is not clear whether patterns found in the study may also be relevant to other suicide methods in Belgium. The study looked at selected socio-economic variables, which due to limitations of data on suicide on the railway network, did not include sex, age, household composition, occupation, and other potentially significant correlates of suicidal behaviour (Gisle & Van Oyen, 2013). Future research, including analysis of individual cases of suicides on railways with regards to socio-demographic and health variables, and proximity and accessibility of railway tracks might further increase our knowledge.

## Conclusion

The geographical study of suicide through PCA helps identifying and explaining the occurrence of railway suicides. An analysis of the environment in which suicides occur, at the local or the regional level, reveals relevant and essential information to explain the spatial variation of suicides. This information is of particular importance for railway companies to prevent suicides in high-risk areas (Havârneanu, Burkhardt, & Paran, 2015). Moreover, the findings show that railway suicide prevention should not be confined to restriction of availability of means (e.g., access to the railways) but should be developed from a broader perspective involving those stakeholders and community representatives who are able to address the population and socio-economic factors germane to railway suicide prevention.

## Disclosure statement

No potential conflict of interest was reported by the authors.

## Note

1. Suburbs are understood as surrounding *arrondissement* of the city centre *arrondissement* of Brussels, Antwerp, and Ghent.

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