Table 6 – Summary of means and standard deviation of the *"shifts"* (a)

Method for Synthex Indicators	Mean of the mean of the shift	Standard deviation of the mean of the shift	Mean of the Standard deviation of the shift	Standard deviation of the Standard deviation of the shift
Index Mean 0-1	2,092	0,828	2,152	0,857
MZ aritmetic mean z-scores	2,224	0,604	2,356	0,631
Jevons static	2,671	1,416	2,752	1,221
MPI	2,183	0,667	2,440	0,938
MPI correct	2,136	0,862	2,288	1,090
IMG	2,006	1,098	2,530	2,057

(a) Results of the robustness test, using the COMIC software - Synthex indicators for road accidents rates by road arch, vehicles fleet and resident population. Year 2016

The application of different weighting criteria leads to very divergent results. The analysis according to the road infrastructures allows purifying a component of mobility of the phenomenon. The seasonal factor due to a more objective measurement also improves the concept of exposure to the risk of being involved in a traffic accident.

Table 7 shows the covariance values, referred to the variation of each variable contained in the matrix in respect of all others.

Table 7 – Covariance Matrix between computing indicators: results obtained by Ranker application

Ranks	Road Arch	Vehicles Fleet	Resident Population
Road Arch	1.0000	0.5278	0.4238
Vehicles Fleet	0.5278	1.0000	0.9390
Resident Population	0.4238	0.9390	1.0000

The values included in table 7 show, in fact, that the risk to be involved in a road accident, within the province of residence (0.4238) or within the vehicle registration province (0.5278) is significantly lower if compared to the indicator out of the length road arch, where the accident occurred.

The road accidents indicators, referred to the road length by province, therefore, allows to obtain a result closer to the road accident risk measures, using traffic flows data. The last data would represent, in fact, the best and correct denominator for road accidents rates.

APPENDIX A

Ranker tool for a composite index computing

A1. Computation and evaluation of composite indices [8]

A *composite index* is a mathematical combination (or aggregation as it is termed) of a set of indicators [1] that represent the different dimensions of a phenomenon to be measured.

Constructing a composite index is a complex task. Its phases involve several alternatives and possibilities that affect the quality and reliability of the results. The main problems, in this approach, concern the choice of theoretical framework, the availability of the data, the selection of the more representative indicators and their treatment in order to compare and aggregate them.

In particular, we can summarize the procedure in the following main steps:

1. *Defining the phenomenon to be measured*. The definition of the concept should give a clear sense of what is being measured by the composite index. It should refer to a theoretical framework, linking various sub-groups and underlying indicators. Also the *model of measurement* must be defined, in order to specify the relationship between the phenomenon to be measured (concept) and its measures (individual indicators). If causality is from the concept to the indicators we have a *reflective model* – indicators are interchangeable and correlations between indicators are explained by the model; if causality is from the indicators to the concept we have a *formative model* – indicators are not interchangeable and correlations between indicators are not explained by the model.
2. *Selecting a group of individual indicators*. The selection is generally based on theory, empirical analysis, pragmatism or intuitive appeal. Ideally, indicators should be selected according to their relevance, analytical soundness, timeliness, accessibility and so on. The selection step is the result of a trade-off between possible redundancies caused by overlapping information and the risk of losing information. However, the selection process also depends on the measurement model used: in a reflective model, all the individual indicators must be intercorrelated; whereas in a formative model they can show negative or zero correlations.
3. *Normalizing the individual indicators*. This step aims to make the indicators comparable. Normalization is required before any data aggregation as the indicators in a data set often have different measurement units. Therefore, it is necessary to bring the indicators to the same standard, by transforming them into pure, dimensionless, numbers. Another motivation for the normalization is the fact that some indicators may be positively

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[8] RankerTool desktop software (http://www.istat.it/en/tools/methods-and-it-tools/analysis-tools/ranker)
i.Ranker web application (https://i.ranker.istat.it)

correlated with the phenomenon to be measured (positive *polarity*) [2], whereas others may be negatively correlated with it (negative *polarity*). We want to normalize the indicators so that an increase in the normalized indicators corresponds to increase in the composite index. There are various methods of normalization, such as *re-scaling* (or Min-Max), *standardization* (or *z*-scores) and 'distance' from a reference (or *index numbers*).

4. *Aggregating the normalized indicators*. It is the combination of all the components to form one or more composite indices (mathematical functions). This step requires the definition of the importance of each individual indicator (weighting system) and the identification of the technique (*compensatory* or *non-compensatory*) for summarizing the individual indicator values into a single number [3]. Different aggregation methods can be used, such as *additive methods* (compensatory approach) or *multiplicative methods* and *unbalance-adjusted functions* (non-compensatory or partially compensatory approach) [4].
5. *Validating the composite index*. Validation step aims to assess the robustness of the composite index, in terms of capacity to produce correct and stable measure, and its discriminant capacity (*Influence Analysis* and *Robustness Analysis*).

A2. The Synthesis Methods

The synthesis methods available on i.ranker are based on the assumption of a formative model:

- Mean of standardised values (MZ);
- Meean of relative index (MR);
- Mazziotta-Pareto index (MPI$^+$/MPI$^-$);

Mean of the standardised values (MZ)

Given the matrix **X**={x_{ij}} of *n* rows (units) and *m* columns (indicators), transformation matrix **Z**={z_{ij}} is built, with:

$$z_{ij} = \begin{cases} \dfrac{(x_{ij} - \mathrm{M}_{x_j})}{\mathrm{S}_{x_j}} & \text{if the indicator j has positive polarity} \\ -\dfrac{(x_{ij} - \mathrm{M}_{x_j})}{\mathrm{S}_{x_j}} & \text{if the indicator j has negative polarity} \end{cases}$$

where M_{x_j} e S_{x_j} are, respectively, mean and standard deviation of the indicator *j*.

The synthex index, for the unit *i*, is given by the formula:

$$\mathrm{MZ}_i = \frac{\sum_{j=1}^{m} z_{ij}}{m}$$

Relative Indices Synthesis (MR)

Given the matrix **X**={x_{ij}} of *n* rows (units) and *m* column (indicators), the transformation matrix **R**={r_{ij}} is built, with:

$$r_{ij} = \begin{cases} \dfrac{(x_{ij} - \mathrm{Min}_{x_j})}{(\mathrm{Max}_{x_j} - \mathrm{Min}_{x_j})} & \text{if the indicator j has positive polarity;} \\ \dfrac{(\mathrm{Max}_{x_j} - x_{ij})}{(\mathrm{Max}_{x_j} - \mathrm{Min}_{x_j})} & \text{if the indicator j has negative polarity;} \end{cases}$$

where Min_{x_j} and Max_{x_j} are, respectively minimum and maximum of the indicators *j*.

The synthex index, for the unit *i*, is given by the formula:

$$\mathrm{MR}_i = \frac{\sum_{j=1}^{m} r_{ij}}{m}.$$

Mazziotta-Pareto index (MPI $^{+}$/MPI $^{-}$)

Given the matrix **X**={x_{ij}} of n rows (units) and *m* columns (indicators), transformation matrix **Z**={z_{ij}}, is built with:

$$z_{ij} = \begin{cases} 100 + \dfrac{(x_{ij} - \mathrm{M}_{x_j})}{\mathrm{S}_{x_j}} 10 & \text{if the indicator j has positive polarity;} \\ 100 - \dfrac{(x_{ij} - \mathrm{M}_{x_j})}{\mathrm{S}_{x_j}} 10 & \text{if the indicator j has negative polarity;} \end{cases}$$

where M_{x_j} e S_{x_j} are, respectively, mean and standard deviation of the indicator *j*.

The synthex index, for the unit *i*, is given by the formula [5] :

$$\mathrm{MPI}_i^{+/-} = \mathrm{M}_{z_i} \pm \mathrm{S}_{z_i} \mathrm{cv}_i$$

dove $\mathrm{M}_{z_i} = \dfrac{\sum_{j=1}^{m} z_{ij}}{m}$; $\mathrm{S}_{z_i} = \sqrt{\dfrac{\sum_{j=1}^{m} (z_{ij} - \mathrm{M}_{z_i})^2}{m}}$; $\mathrm{cv}_i = \dfrac{\mathrm{S}_{z_i}}{\mathrm{M}_{z_i}}$.

A3. The synthesis method

Table A1 contains a list of the main features of available methods, to select a suitable synthex index to the phenomenon studied.

The advantages of a synthex index can be summarized in:

(a) one-dimensional measurement of a complex phenomenon,

(b) easy interpretation in respect to a set of elementary indicators ("dashboard"),

(c) simplification of data analysis (in particular, ordering of geographical units).

Table A1 shows the main features of available method.

Table A1. Methods of indices synthesis features

Method of synthesis	Main features
Mean of standardised values (MZ)	Compensatory method It is based on the arithmetic mean of the z-scores. Mean 0 range between -3 and +3. Assumption: the indicators have the same variability.
Mean of relative indices (MR)	Compensatory method It is based on the arithmetic mean of the relative values. Range between 0 and 1. Does not exist a fixed mean.
Mazziotta-Pareto index (MPI^+/MPI^-)	Non-compensatory method It is based on an arithmetic mean penalized on the basis of the imbalance of values. Mean equal to 100, range between 70 and 130 Assumption: the indicators have the same variability. It is applicable to both positive events (MPI-) and negative (MPI +). It can be divided into two parts: "medium" (compensatory) effect and "penalty" effect (imbalance).

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[1] An simple indicator is computed data by means the ratio of a “raw” to a reference base (for example, “per capita income”).

[2] The polarity of an indicator is the sign of the relationship between the indicator and the phenomenon to be measured

[3] A simple indicator is considered “substitutable” if a deficit of an indicator can be compensated by a surplus in other.

[4] A simple indicator is considered “not substitutable” if a deficit of an indicator cannot be compensated by a surplus in other.

[5] If the composite index is ‘increasing’ or ‘positive’, i.e., increasing values of the index correspond to positive variations of the phenomenon (e.g., the socio-economic development), then MPI- is used. Vice versa, if the composite index is ‘decreasing’ or ‘negative’, i.e., increasing values of the index correspond to negative variations of the phenomenon (e.g., the poverty), then MPI+ is used.

APPENDIX B
Maps of main road arches from OpenStreetMap

Chart B1. Primary Roads. Year 2016 (Open Street Map)

Chart B2. Secondary Roads. Year 2016 (Open Street Map)

Chart B3. Motorways. Year 2016 (Open Street Map)

Chart B4. Trunks. Year 2016 (Open Street Map)