# SI for 'From global scaling to the dynamics of individual cities'

**Jules Depersin**[a] **and Marc Barthelemy**[a, b]

[a]Institut de Physique Théorique, Université Paris Saclay, CEA, CNRS, F-91191 Gif-sur-Yvette, France; [b]Centre d'Analyse et de Mathématique Sociales, (CNRS/EHESS) 54, Boulevard Raspail, 75006 Paris, France

## 1. Dataset description

The dataset is freely available (1) and the methodology is described in the Urban mobility report, 2012 of the Texas A&M Transportation Institute (TTI), College Station, Texas (2).

This dataset has also been studied in (3) and contains the total hours of delays, excess fuel consumption, and excess $CO_2$ emission due to congestion for 101 of the largest urban centers in the US. The data spans a 30-year period from 1982 to 2011. Other information such as the population size, number of commuters, the freeway's lane-miles, and the lane-miles of arterial streets, are also available at the same source.

**A. Population size.** The group of the 101 urban centers described in this dataset is very heterogeneous and contains cities with very different population (see Fig. S1). We see on this figure that indeed the population of the 101 cities varies from $10^5$ to

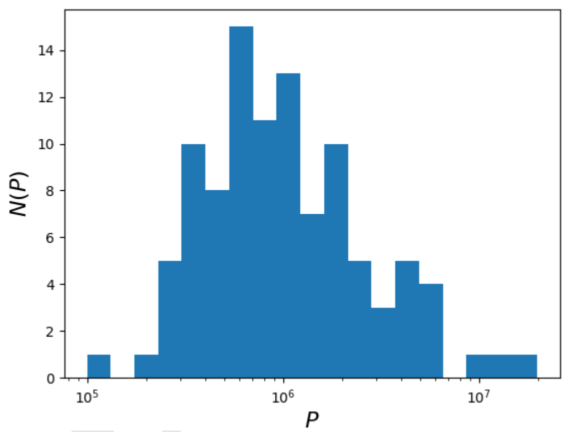


**Fig. S1.** Histogram for the population of the 101 cities considered in the dataset used in this study.

very large numbers of the order $10^7$.

**B. Spatial distribution of cities.** The spatial distribution of the cities in this dataset appears to be uniform as can be seen on the map shown in Fig. S2. This points to the probable absence of spatial bias in the selection of these cities.

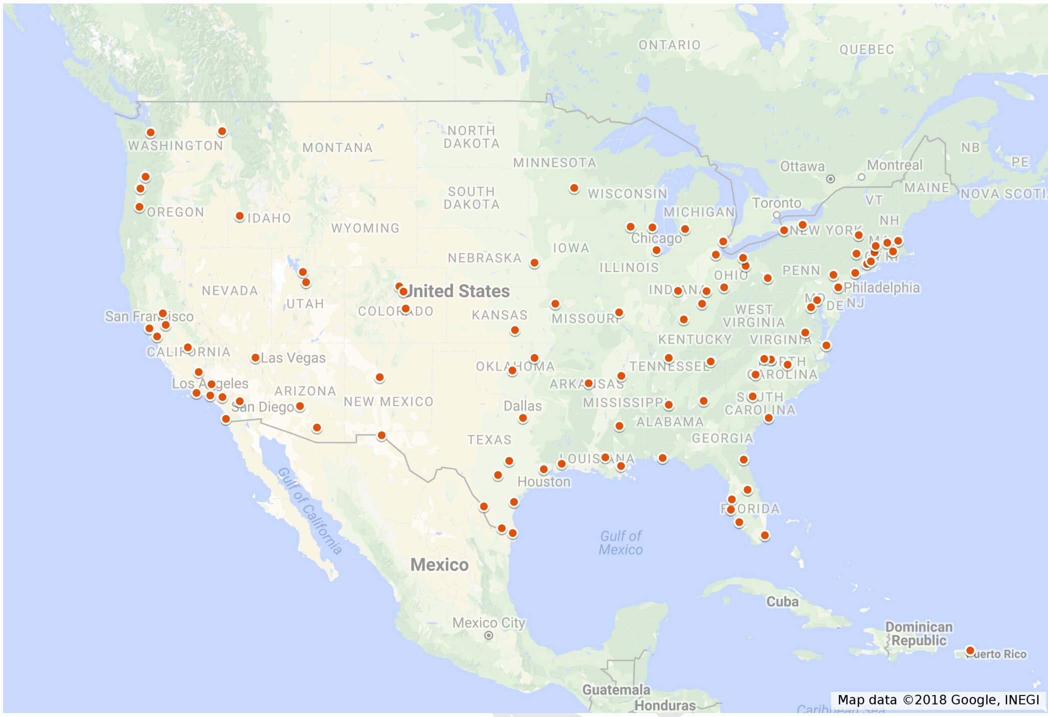


**Fig. S2.** Spatial distribution of the cities studied in the dataset [19].

## 2. Exponents

**A. Type-1 cities.** For this set of cities, the total annual delay behaves as

$$\delta\tau \sim P^{\beta} \qquad \text{[S1]}$$

We report in the table S1 the list of values for the exponent $\beta$ for cities in this set.

| Cities | $\beta$ |
|---|---|
| Bakersfield CA | 3.1962881588682959 |
| Baltimore MD | 2.1270202500885378 |
| Beaumont TX | 4.3121047081974959 |
| Brownsville TX | 3.0747686515178829 |
| Buffalo NY | 4.2755491010100437 |
| Corpus Christi TX | 2.2675957429714364 |
| Denver-Aurora CO | 1.9671893783052652 |
| Fresno CA | 1.7450280827103009 |
| Hartford CT | 4.2648453780225291 |
| Laredo TX | 2.7791991465460999 |
| Los Angeles-Long Beach-Anaheim CA | 1.6285956803032693 |
| Madison WI | 2.0708101241687573 |
| Miami FL | 1.7546710159878378 |
| New York-Newark NY-NJ-CT | 2.4298069942492848 |
| Phoenix-Mesa AZ | 1.1968694416385248 |
| Poughkeepsie-Newburgh NY-NJ | 2.2768614183888238 |
| Riverside-San Bernardino CA | 2.2120810624454421 |
| Rochester NY | 2.7673045447707381 |
| Sacramento CA | 1.8017150060867237 |
| Salt Lake City-West Valley City UT | 2.9767035187758353 |
| San Diego CA | 2.0458776650851993 |
| San Francisco-Oakland CA | 1.6629530945958924 |
| San Juan PR | 3.1783030977078384 |
| Sarasota-Bradenton FL | 1.4488835644752018 |
| Seattle WA | 1.6121623183491192 |
| Springfield MA-CT | 2.6800144800260295 |
| Stockton CA | 2.1574496507830698 |
| Tampa-St. Petersburg FL | 1.6447950508957183 |
| Toledo OH-MI | 3.3688674059068782 |
| Tulsa OK | 2.7543394208073106 |
| Virginia Beach VA | 2.6761368087062629 |

**Table S1. Table for the exponent $\beta$ for type-1 cities.**



We checked that the exponent is not correlated with for example the final value of the population (see Fig. S3, left), but seems to display some non-negligible correlation with the average growth rate of a city (Fig. S3, right): a linear fit gives a value of $-42.8$ and a $p-$value of order 1% (we have however to be careful with these results as the number of points is small 35). Certainly more work is needed here in order to study and understand these correlations.

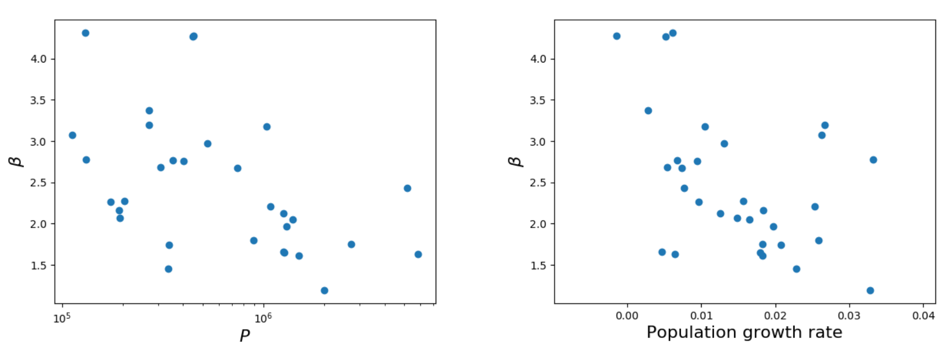


**Fig. S3.** Exponent $\beta$ for type-1 cities versus (left) the population in 2014 and (right) the average population growth rate.

**B. Type-2 cities.** By definition, for these cities, the total annual delay displays two regimes:

$$\delta\tau \sim \begin{cases} P^{\beta_1} \text{ when } P < P^* \\ P^{\beta_2} \text{ when } P > P^* \end{cases} \quad \text{[S2]}$$

We report in the table S2 the values for the exponents $\beta_1$ and $\beta_2$ computed for cities in this set.

| Cities | $\beta_1$ | $\beta_2$ |
|---|---|---|
| Akron OH | 13.326474795174038 | 0.87036942722175636 |
| Albuquerque NM | 2.5254001684820788 | 0.43854750637699613 |
| Allentown PA-NJ | 3.5421104701666195 | -0.067986378704719463 |
| Anchorage AK | 4.4297963653591861 | 1.8793584427200676 |
| Baton Rouge LA | 11.668425227500549 | 1.8982765309794534 |
| Birmingham AL | 5.7127486536782648 | 1.0950883331666841 |
| Boston MA-NH-RI | 3.7914578273352344 | 0.77783357746260684 |
| Cape Coral FL | 2.0170904969164649 | -0.026908122725563643 |
| Charleston-North Charleston SC | 2.4180178167624629 | 0.73588836271136682 |
| Cincinnati OH-KY-IN | 13.391227137876555 | 1.4320691394968488 |
| Colorado Springs CO | 3.5302691471058441 | 0.90526757676454483 |
| Dayton OH | 10.888618834160816 | 1.5156113313272581 |
| El Paso TX-NM | 2.9723440807376567 | 0.38670363662700824 |
| Eugene OR | 9.6712863372110895 | 1.6336801378157653 |
| Grand Rapids MI | 4.9081888328711596 | 1.5063662641986844 |
| Greensboro NC | 4.2842149874033737 | 1.6655920377612741 |
| Honolulu HI | 2.6651812393270475 | 0.77842406987398327 |
| Indianapolis IN | 2.6903465538846123 | 1.090315534230037 |
| Jackson MS | 1.9548784600955464 | 4.7321108315657057 |
| Kansas City MO-KS | 7.5792226148887991 | 1.5218080339581797 |
| Knoxville TN | 5.3636780273848892 | 0.93514977131710486 |
| Lancaster-Palmdale CA | 1.2247810270154447 | 2.9739214893281631 |
| Little Rock AR | 4.7652094890503749 | 1.4888932143083471 |
| Louisville-Jefferson County KY-IN | 3.5668794174079124 | 0.9138483476564403 |
| McAllen TX | 2.4226867170036792 | 0.97162477887304632 |
| Memphis TN-MS-AR | 5.4918835943332702 | 1.8984236927813019 |
| Milwaukee WI | 7.421602499615239 | 1.4476849327745018 |
| New Haven CT | 6.6974370590880659 | 1.7283783197405369 |
| Oklahoma City OK | 3.5828355912773997 | 0.96908077750423693 |
| Omaha NE-IA | 5.2900061281968238 | 1.8104815755057855 |
| Oxnard CA | 4.2415757905874498 | 0.76412979056781882 |
| Pensacola FL-AL | 3.4069992036124965 | 1.3307657898250249 |
| Philadelphia PA-NJ-DE-MD | 8.8036825555975149 | 1.864839051262341 |
| Pittsburgh PA | 12.933233804630934 | 1.6230810430641514 |
| Providence RI-MA | 6.0658243195175512 | 1.8788870804188385 |
| Raleigh NC | 3.7254322679051999 | 1.5426528575241691 |
| Salem OR | 10.698703161001736 | 1.6924113979752105 |
| San Antonio TX | 2.1755450079365595 | 0.93642743110819815 |
| San Jose CA | 6.1181308990910814 | 2.0497802182301532 |
| St. Louis MO-IL | 4.0680015596238288 | 1.3568682133833097 |
| Washington DC-VA-MD | 2.4099008223841625 | 0.57016625283470113 |
| Wichita KS | 3.713495596552173 | 1.4821634370695835 |
| Winston-Salem NC | 2.003627578146336 | -0.11462030190236838 |

**Table S2. Table for the exponents $\beta_1$ and $\beta_2$ for type-2 cities.**

## 3. Correlation between $\beta_1$ and $\beta_2$

For type-2 cities we plot $\beta_2$ versus $\beta_1$ in the Fig. S4. We observe in this figure that there are no significant correlations between

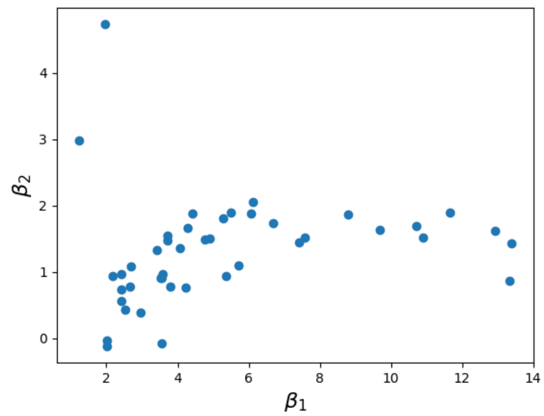


**Fig. S4.** Type-2 cities: exponent $\beta_2$ versus $\beta_1$.

these exponents (the $p-$value for the regression is $0.27 > 0.05$ and we cannot reject the hypothesis of no correlations).

## 4. Distribution of $T^*$, $P^*$, $(\delta\tau/P)^*$

For type-2 cities, we show here the distributions of the quantities defined at the change of slope: $T^*$ is the time at which the slope happened, $P^*$ is the corresponding population and $(\delta\tau/P)^*$ is the delay per capita when it happened.

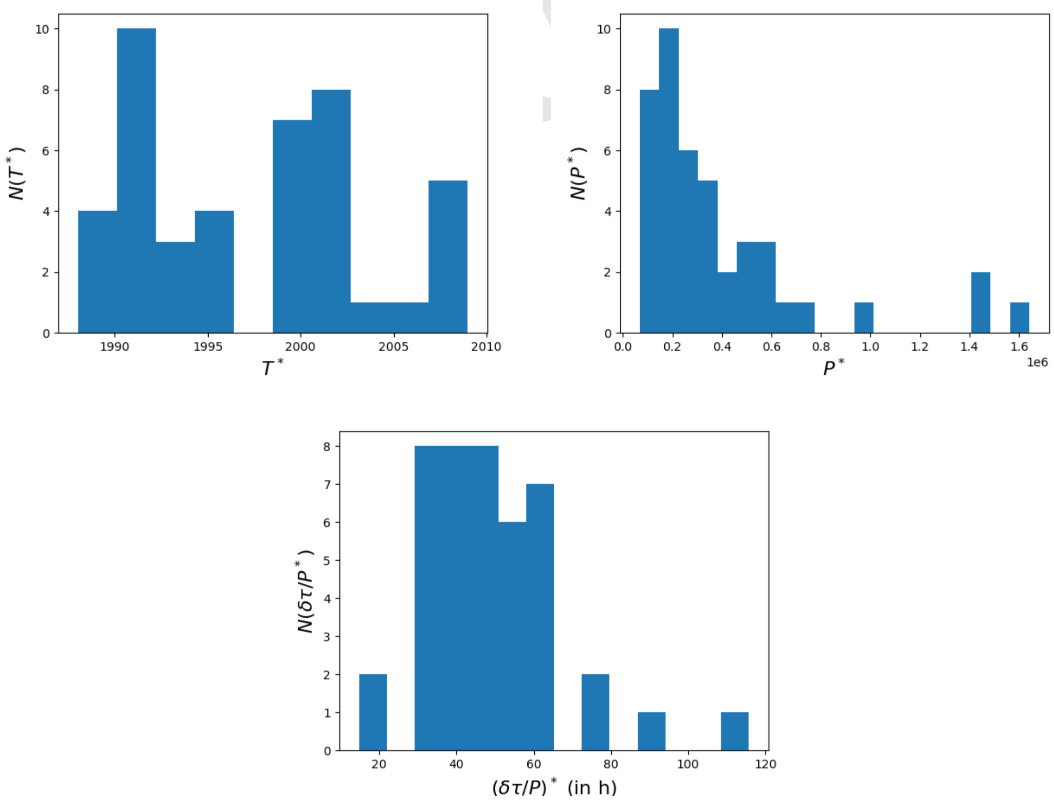


**Fig. S5.** Empirical histograms for $T^*$, $P^*$ (in unit of million inhabitants) and $(\delta\tau/P)^*$ (in unit of hours). In particular the histogram for $(\delta\tau/P)^*$ shows that the changes of slope in type-2 cities appears approximately at the same value of about $40$ hours per year and per capita of congestion induced delay.

## Bibliography


1. http://tti.tamu.edu/documents/ums/congestion-data/complete-data.xlsx
2. http://mobility.tamu.edu/ums/methodology
3. Chang YS, Lee YJ, Choi SS (2017) Is there more traffic congestion in larger cities? -Scaling analysis of the 101 largest U.S. urban centers. *Transport Policy*. 59:54-63.