

TRANSPORT FINDINGS

Streetcar and Interurban Deployment in the United States: 1894-1926

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Findings

We compile operating track lengths for US streetcar and interurban systems from the McGraw American Street Railway Investments Directories for 1894–1926, aggregated by state and by metro area, with a national total. The United States network reaches an observed maximum of 80,660 km (50,120 miles) in 1918, with a logistic asymptote of 84,208 km, inflection year 1901, and $R^2 = 0.89$. We report cities and states by extent and timing, and show that most city and state series follow logistic S-curves.

1. Questions

While qualitative descriptions of US streetcar history are plentiful (e.g. Warner (1978)) and there is a catalog of electric interurbans in the US (Hilton and Due 1964), no wide-scale quantitative studies of streetcars exist, with most being limited to singular cities or states (e.g. Xie and Levinson (2010)). This paper conducts a quantitative analysis of streetcar adoption, modelled under the framework of Rogers (1995) theory on the diffusion of innovations. S-curves for the adoption of technologies have often been studied, in fields ranging from electric vehicles (Graham 2022) to digital signal processors (Nieto, López, and Cruz 1998). We seek to answer the following questions:

1. What are the magnitudes and timing of streetcar system extents by metro area and state and the US national total, over 1894–1926? Where and when did the network peak?
2. Do these systems exhibit logistic S-curve growth, and does the growth rate vary systematically with timing?

2. Methods

We assemble annual series of in-service route-kilometres for streetcars and interurbans for selected metropolitan areas and for the United States total, drawing on the McGraw *American Street Railway Investments* directories and related sources listed in the Supplemental Information. Published between 1894 and 1932, these directories detail streetcar and electric interurban railway (hereafter collectively referred to as streetcar) systems by city, state and company. We use the length of track recorded in these directories to analyse the growth of streetcars in America.

Streetcar track lengths, as recorded in the *McGraw Directories*, are used to proxy for streetcar growth and adoption. We analysed the years between 1894 and 1926. The 1895, 1896, 1915 and 1916 directories were not available for analysis. Due to significant data discrepancies, 1912 and 1913 were not used for this analysis.

The original directories have been scanned and are archived by the HathiTrust Digital Library and are available online as PDFs. To turn them into a machine readable format, we processed the directories with ABBYY FineReader, an optical character recognition (OCR) program (ABBYY 2013).

Regular expression string matching was used to obtain a data table of track lengths by company, city, state and year. No distinction was made between local streetcar systems and interurbans, as often these would travel on the same tracks and were operated by the same organisation. Although the directories sometimes included incomplete track, or track under construction, only completed, operating track was kept. Mode (horse vs cable vs electric) was not kept.

The machine-extracted data was post-processed manually to increase accuracy. Validation was performed against hand-extracted values from 1894-1920 done previously as unpublished classwork by students at the University of Sydney.

For each series we model the cumulative route-kilometres $S(t)$ as a logistic function of calendar year t ,

$$S(t) = \frac{K}{1 + e^{-b(t-t_i)}} \quad (1)$$

where K is the long-run saturation level, b is the growth rate, and t_i is the inflection year, all variables defined in [Table 1](#). We estimate the parameters (K, b, t_i) for each city and for the national total by ordinary least squares on Equation (1), using all years with observed data. Modelling details are provided in the Supplemental Information. For each series we report the fitted parameters, the coefficient of determination R^2 , and the observed maximum route-kilometres and its year (Tables S1–S4).

The S-curve was only applied to the growth period, with the end of the growth period being determined by the year the maximum observed value occurred. S-curves were modelled by city and state, where the observed maximum was greater than 100 miles (160 km) of track, and more than five years of observed growth was available.

Table 1. Notation

Symbol	Meaning [units]
$S(t)$	Track length at year t [km]
K	Asymptotic maximum track length [km]
b	Logistic growth rate parameter [1/year]
t	Year [calendar year]
t_i	Inflection year, where $S = 0.5K$ [calendar year]
$T_{\max}$	Observed maximum track length [km]

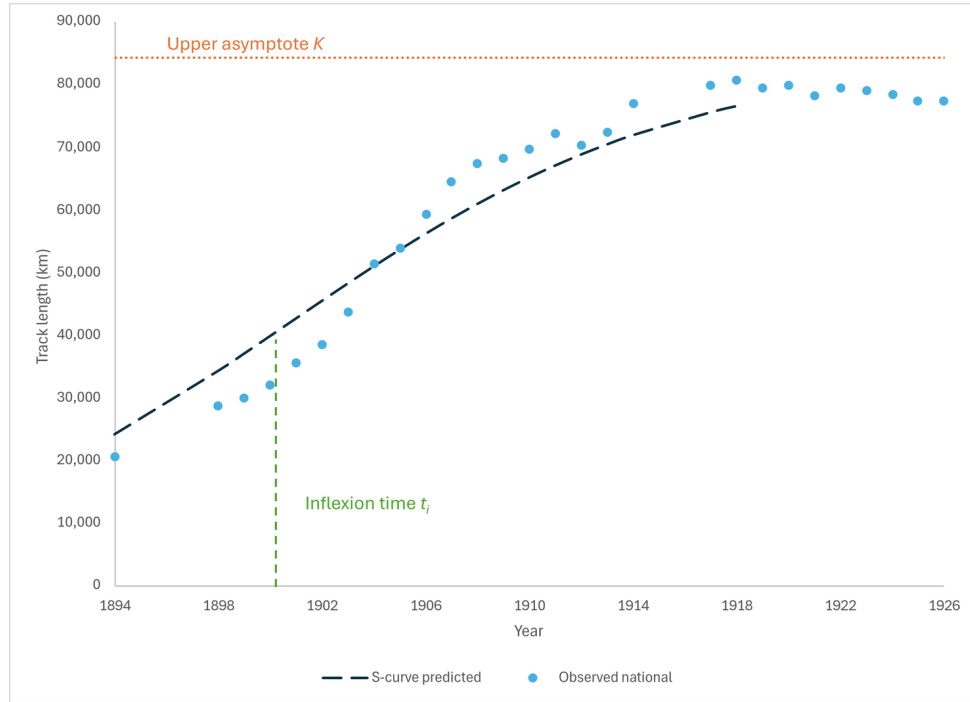


Figure 1. National United States S-curve. **National total:** United States observed maximum 80,660 km (1918); fitted $K = 84,208$ km; $t_i = 1901$; $b = 0.134$; $R^2 = 0.89$

3. Findings

3.1. Magnitudes and timing

We find that the United States reached an observed maximum of 80,660 *km* in 1918 ([Figure 1](#)).

The largest metro areas were Chicago, IL 6,527 *km* (1926), New York City, NY 5,248 *km* (1918), Boston, MA 3,922 *km* (1908), Los Angeles, CA 2,388 *km* (1920), Detroit, MI 2,159 *km* (1925), Pittsburgh, PA 2,045 *km* (1910). The median inflection year across metros is 1909. See [Table 2](#) for details.

The most extensive streetcar systems were found in the following states: New York 10,371 *km* (1918), Illinois 8,818 *km* (1922), Pennsylvania 8,468 *km* (1914), Ohio 7,011 *km* (1907), California 6,762 *km* (1925), Massachusetts 6,540 *km* (1911). Across states, the median inflection year is 1903.5

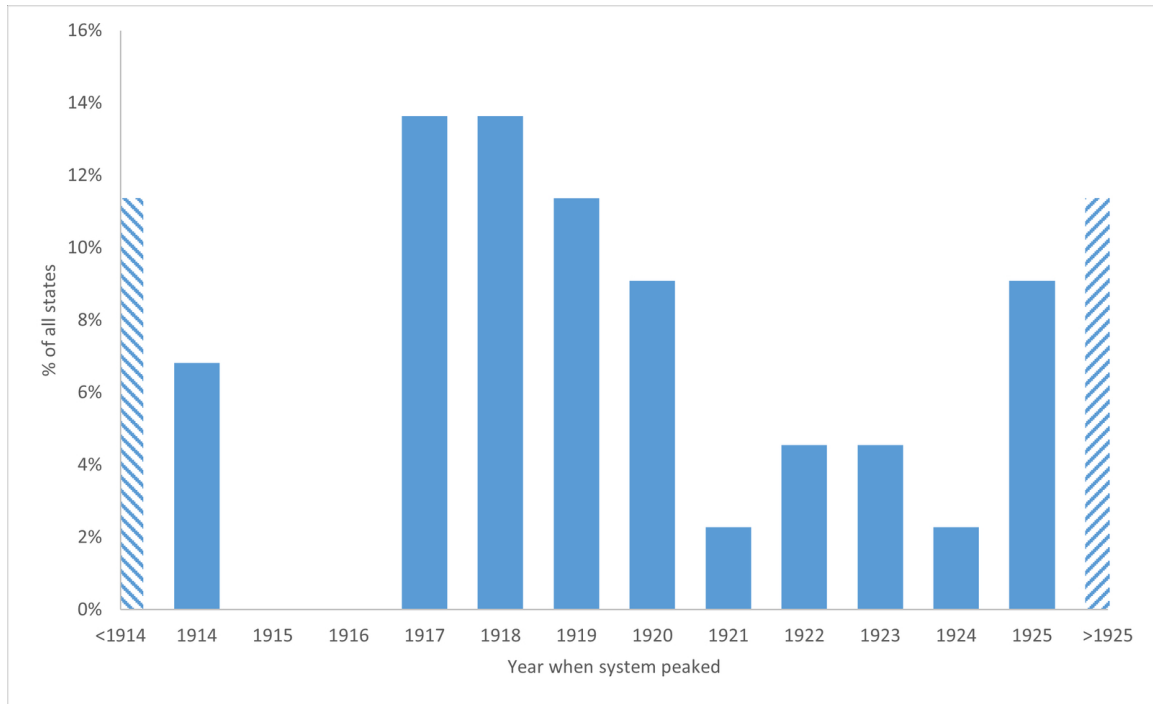


Figure 2. Proportion of states peaking by year

Only 14% of states peaked in the same year (1918) as the national system, most notably New York. The spread of peak years amongst states is varied across the 1910s and 1920s ([Figure 2](#)). 25 of 44 states peak by 1919, and 19 of 44 from 1920–1926. See [Table 3](#) for details.

3.2. Trends

We do not find a robust increase in b for later t_i across metros or states (see [Figure 3](#) and SI), indicating that institutional and financial factors likely dominate simple diffusion-timing expectations.

However, logistic fits are strong: 102 of 152 metros and 40 of 44 states have $R^2 > 0.7$. We see that the aggregation to state-level improves the logistic fit, consistent with smoothing of local discontinuities (See [Figure 4](#) and Figure 9; [Table 2](#) and [Table 3](#)).

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Table 3. S-curve statistics for states

Location	Obs. max. (km)	Year obs.	Theor. max. (km)	<i>b</i> -value	Inflection year	<i>R</i> ²
Alabama	673	1925	752	0.078	1902	0.9
Arkansas	211	1919	225	0.132	1901	0.83
California	6762	1925	6841	0.206	1907	0.92
Colorado	820	1910	898	0.175	1900	0.76
Connecticut	2598	1917	2676	0.194	1906	0.86
D. C	687	1918	766	0.121	1903	0.89
Delaware	256	1920	259	0.174	1905	0.58
Florida	327	1920	365	0.14	1907	0.97
Georgia	870	1924	948	0.098	1901	0.97
Idaho	190	1918	196	0.334	1910	0.87
Illinois	8818	1922	8896	0.156	1906	0.84
Indiana	4767	1908	4846	0.398	1903	0.75
Iowa	1739	1923	1819	0.145	1905	0.96
Kansas	889	1917	969	0.127	1911	0.65
Kentucky	842	1914	921	0.164	1904	0.8
Louisiana	528	1918	607	0.079	1899	0.84
Maine	930	1921	951	0.177	1902	0.95
Maryland	1147	1920	1226	0.135	1899	0.86
Massachusetts	6540	1911	6619	0.29	1898	0.91
Michigan	3548	1923	3627	0.138	1905	0.82
Minnesota	1363	1926	2021	0.068	1915	0.95
Mississippi	199	1918	214	0.205	1906	0.93
Missouri	1976	1914	2055	0.21	1898	0.9
Montana	449	1918	528	0.13	1913	0.72
Nebraska ^a	369	1917	370	0.11	1889	0.29
Nebraska ^b	369	1917	398	0.123	1897	0.91
New Hampshire	487	1905	566	0.326	1901	0.8
New Jersey	2578	1920	2657	0.156	1900	0.91
New York	10371	1918	10449	0.224	1902	0.9
North Carolina	621	1922	700	0.153	1914	0.93
Ohio	7011	1907	7091	0.433	1900	0.81
Oklahoma	597	1926	616	0.252	1912	0.99
Oregon	1216	1925	1294	0.162	1909	0.94
Pennsylvania	8468	1914	8547	0.342	1900	0.93
Rhode Island	739	1917	740	0.271	1897	0.77
South Carolina	240	1919	278	0.112	1905	0.9
Tennessee	834	1926	1249	0.045	1913	0.88
Texas	1775	1919	1854	0.181	1906	0.81
Utah	822	1925	901	0.156	1911	0.92
Vermont	205	1917	209	0.177	1899	0.71
Virginia	777	1926	842	0.08	1894	0.61
Washington	1963	1919	2042	0.205	1906	0.94
West Virginia	1121	1919	1201	0.203	1909	0.95
Wisconsin	1303	1926	1329	0.138	1900	0.96

^a When considering entire 1894-1926 period^b When considering post-1902 only

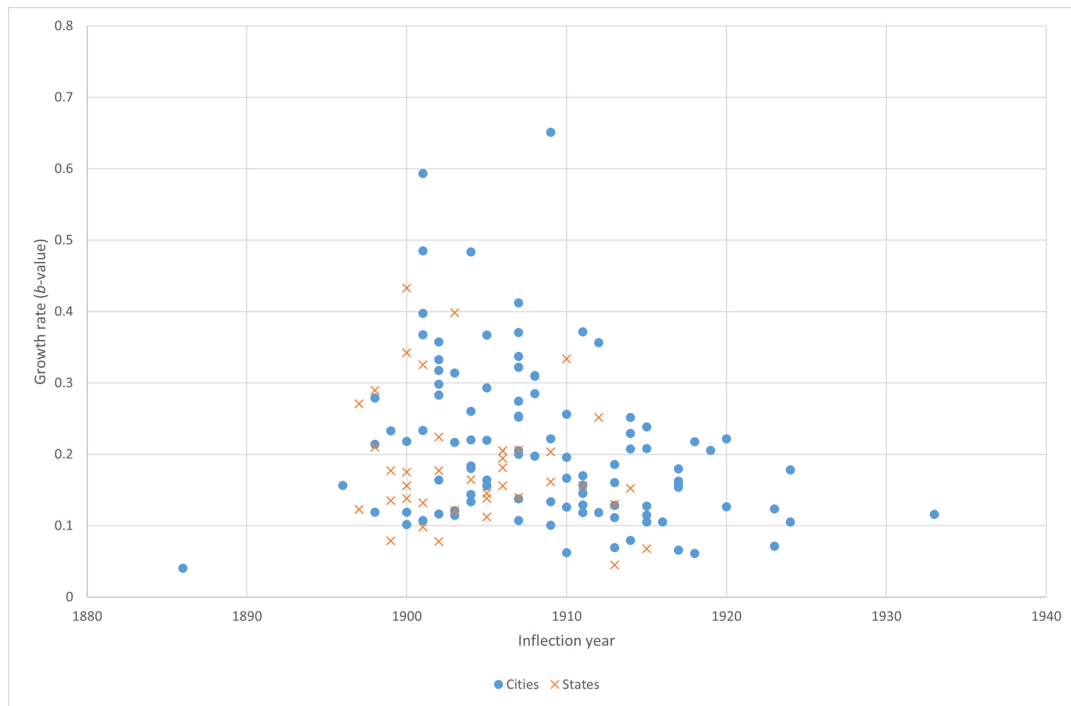


Figure 3. Estimated growth rate b versus inflection year t_i .

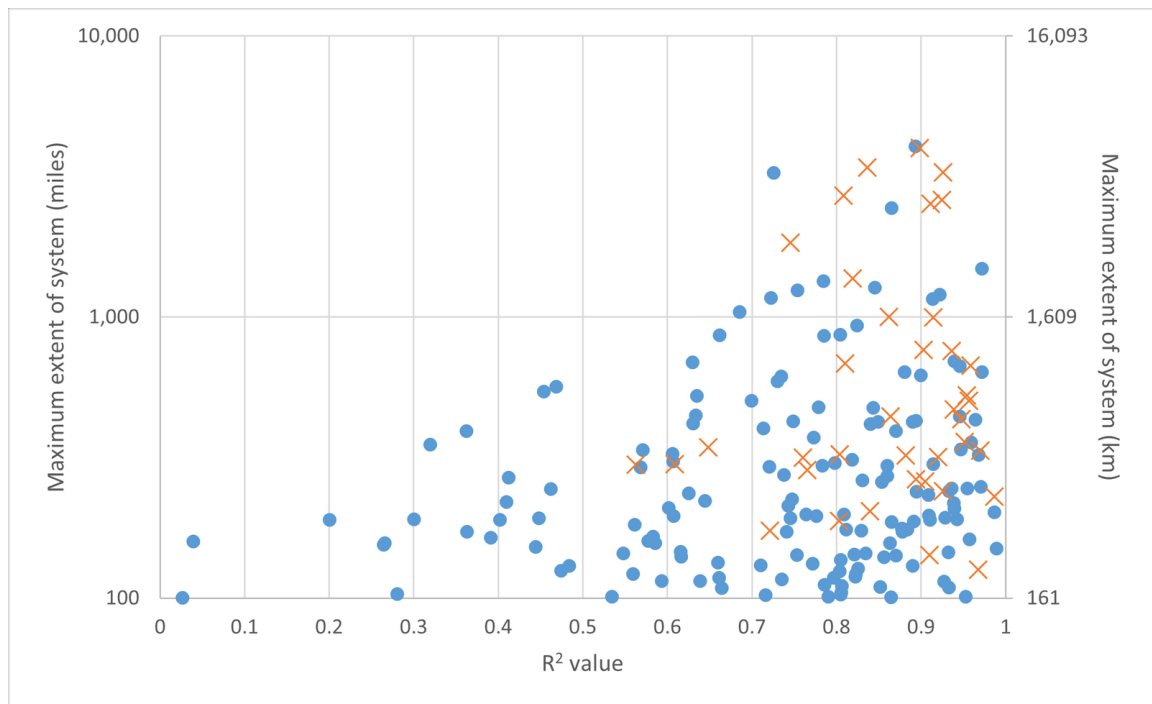


Figure 4. R^2 against maximum system length.

Table 2. S-curve statistics for cities with systems over 100 miles (160 km) at maximum extent

Location	Obs. max. (km)	Year obs.	Theor. max. (km)	b-value	Inflection year	R ²
Akron, Ohio	475	1926	499	0.133	1909	0.86
Albany, New York	280	1921	359	0.118	1911	0.83
Allentown, Pennsylvania	633	1924	711	0.105	1915	0.87
Alliance, Ohio	185	1905	264	0.341	1908	0.59
Alton, Illinois	220	1925	299	0.105	1924	0.81
Altoona, Pennsylvania	162	1910	241	0.205	1907	0.86
Anaconda, Montana	252	1917	332	0.1	1938	0.27
Anderson, Indiana	1075	1909	1154	0.483	1904	0.95
Athol, Massachusetts	235	1919	314	0.147	1925	0.62
Atlanta, Georgia	521	1923	600	0.107	1907	0.97
Atlantic City, New Jersey	343	1923	373	0.161	1913	0.74
Auburn, New York	185	1910	264	0.285	1908	0.93
Aurora, Illinois	354	1917	380	0.136	1915	0.41
Baltimore, Maryland	949	1914	1028	0.119	1900	0.73
Birmingham, Alabama	438	1926	605	0.066	1917	0.86
Bloomington, Illinois	293	1907	372	0.32	1908	0.56
Bluefield, West Virginia	256	1924	257	0.156	1909	0.04
Boone, Iowa	315	1920	394	0.222	1920	0.78
Boston, Massachusetts	3922	1908	4001	0.397	1901	0.86
Bridgeport, Connecticut	395	1914	406	0.298	1902	0.95
Bridgeton, New Jersey	310	1919	389	0.086	1927	0.45
Brockton, Massachusetts	770	1902	848	0.593	1901	0.78
Buffalo, New York	1027	1920	1106	0.116	1902	0.88
Camden, New Jersey	229	1905	307	0.164	1902	0.75
Champaign, Illinois	1380	1914	1460	0.371	1911	0.79
Charlotte, North Carolina	375	1922	454	0.205	1919	0.91
Chattanooga, Tennessee	161	1919	172	0.016	1833	0.03
Chicago, Illinois	6527	1926	9790	0.071	1923	0.89
Chico, California	350	1917	352	0.651	1909	0.94
Cincinnati, Ohio	1880	1908	1959	0.318	1902	0.72
Cleveland, Ohio	1394	1926	1421	0.119	1898	0.8
Columbus, Ohio	686	1906	764	0.333	1902	0.75
Dallas, Texas	672	1917	750	0.14	1914	0.63
Danville, Illinois	875	1908	954	0.396	1909	0.45
Davenport, Iowa	277	1923	356	0.079	1914	0.74
Dayton, Ohio	811	1905	890	0.429	1902	0.7
Decatur, Illinois	185	1911	264	0.185	1913	0.64
Denver, Colorado	525	1911	604	0.105	1900	0.61
Des Moines, Iowa	302	1926	312	0.156	1905	0.89
Detroit, Michigan	2159	1925	2237	0.138	1907	0.78
Duluth, Minnesota	277	1914	356	0.066	1913	0.36
East Liverpool, Ohio	163	1918	241	0.127	1920	0.79
East St. Louis, Illinois	542	1919	547	0.239	1909	0.57
Easton, Pennsylvania	216	1914	295	0.14	1910	0.66
El Paso, Texas	166	1920	229	0.159	1917	0.81
Erie, Pennsylvania	473	1925	546	0.105	1916	0.72
Evansville, Indiana	384	1918	455	0.196	1910	0.89

Location	Obs. max. (km)	Year obs.	Theor. max. (km)	<i>b</i> -value	Inflection year	<i>R</i> ²
Fairmont, West Virginia	311	1921	389	0.208	1915	0.93
Fort Dodge, Iowa	282	1910	336	1.001	1909	0.81
Fort Wayne, Indiana	719	1907	798	0.396	1906	0.63
Fort Worth, Texas	305	1917	385	0.145	1911	0.91
Fostoria, Ohio	167	1925	167	0.251	1913	0.28
Ft Wayne, Indiana	494	1925	573	0.136	1915	0.61
Galesburg, Illinois	233	1904	311	0.295	1906	0.55
Galveston, Texas	249	1914	275	0.09	1916	0.26
Georgetown, Massachusetts	211	1906	290	0.412	1907	0.71
Glens Falls, New York	335	1919	414	0.207	1914	0.94
Gloversville, New York	205	1914	208	0.279	1898	0.83
Grand Rapids, Michigan	395	1908	473	0.314	1903	0.94
Harrisburg, Illinois	394	1926	591	0.301	1931	0.46
Harrisburg, Pennsylvania	306	1905	385	0.153	1905	0.4
Hartford, Connecticut	306	1919	307	0.149	1906	0.2
Haverhill, Massachusetts	337	1917	415	0.142	1915	0.6
Hazleton, Pennsylvania	201	1919	280	0.071	1924	0.47
Highwood, Illinois	307	1925	309	0.225	1912	0.3
Houston, Texas	226	1924	233	0.14	1911	0.62
Indianapolis, Indiana	1680	1908	1759	0.302	1905	0.69
Jackson, Michigan	671	1920	750	0.239	1915	0.84
Jamestown, New York	196	1914	275	0.17	1911	0.82
Joliet, Illinois	230	1906	309	0.293	1905	0.82
Joplin, Missouri	163	1914	241	0.222	1909	0.95
Kalamazoo, Michigan	244	1918	246	0.193	1907	0.44
Kansas City, Missouri	695	1924	768	0.114	1903	0.96
Kittanning, Pennsylvania	264	1920	343	0.102	1937	0.39
La Salle, Illinois	191	1909	269	0.242	1910	0.66
Lancaster, Pennsylvania	362	1908	441	0.22	1904	0.75
Lansing, Michigan	315	1907	394	0.304	1909	0.61
Lawrence, Massachusetts	258	1902	336	0.237	1901	0.58
Lewiston, Maine	316	1918	349	0.197	1908	0.91
Lima, Ohio	417	1917	422	0.371	1907	0.85
Long Island City, New York	1113	1911	1193	0.357	1907	0.63
Los Angeles, California	2388	1920	2467	0.254	1907	0.97
Louisville, Kentucky	500	1914	579	0.133	1904	0.82
Memphis, Tennessee	234	1926	253	0.102	1900	0.93
Milford, Massachusetts	176	1907	190	0.485	1901	0.93
Milwaukee, Wisconsin	712	1926	748	0.107	1901	0.95
Minneapolis, Minnesota	1025	1926	1392	0.069	1913	0.97
Montreal, Quebec	566	1922	566	0.134	1904	0.32
Nashville, Tennessee	284	1926	425	0.061	1918	0.88
New Bedford, Massachusetts	469	1920	549	0.1	1920	0.57
New Haven, Connecticut	1869	1926	2060	0.186	1913	0.91
New Orleans, Louisiana	386	1924	465	0.041	1886	0.93
New York City, New York	5248	1918	5327	0.18	1904	0.73
Newark, New Jersey	1504	1921	1539	0.184	1904	0.82

Location	Obs. max. (km)	Year obs.	Theor. max. (km)	<i>b</i> -value	Inflection year	<i>R</i> ²
Newton, Massachusetts	210	1914	288	0.107	1911	0.48
Norfolk, Virginia	307	1910	386	0.26	1904	0.94
Norristown, Pennsylvania	266	1920	325	0.1	1914	0.58
Norwich, Connecticut	357	1918	436	0.145	1921	0.64
Norwood, Massachusetts	201	1923	209	0.251	1914	0.8
Oakland, California	601	1918	679	0.101	1909	0.77
Ogden, Utah	282	1923	360	0.218	1918	0.88
Oil City, Pennsylvania	192	1918	270	0.179	1917	0.82
Oklahoma City, Oklahoma	241	1919	259	0.356	1912	0.99
Omaha, Nebraska	232	1924	233	0.157	1896	0.83
Oneida, New York	190	1921	269	0.178	1924	0.8
Oshkosh, Wisconsin	163	1924	241	0.049	1933	0.53
Peoria, Illinois	1388	1920	1468	0.18	1916	0.66
Philadelphia, Pennsylvania	1932	1914	2010	0.218	1900	0.92
Pittsburg, Kansas	169	1921	171	0.309	1908	0.81
Pittsburgh, Pennsylvania	2045	1910	2124	0.283	1902	0.85
Pittsfield, Massachusetts	261	1917	274	0.31	1908	0.96
Portland, Maine	175	1917	175	0.236	1900	0.66
Portland, Oregon	1119	1925	1197	0.167	1910	0.94
Providence, Rhode Island	683	1918	690	0.233	1899	0.89
Reading, Pennsylvania	646	1922	726	0.115	1915	0.71
Richmond, Virginia	486	1917	565	0.126	1910	0.8
Rochester, New York	991	1914	1070	0.2	1907	0.73
Rockford, Illinois	380	1919	417	0.153	1912	0.63
Sacramento, California	431	1919	510	0.086	1930	0.41
Salt Lake City, Utah	544	1926	705	0.111	1913	0.95
San Bernardino, California	320	1922	340	0.229	1914	0.81
San Diego, California	476	1925	555	0.163	1917	0.78
San Francisco, California	1999	1925	2078	0.157	1911	0.75
San Jose, California	300	1919	378	0.128	1913	0.87
San Luis Obispo, California	165	1922	243	0.116	1933	0.72
Saratoga Springs, New York	179	1911	180	1.62	1909	0.79
Schenectady, New York	225	1917	227	0.367	1905	0.86
Scranton, Pennsylvania	401	1925	480	0.118	1912	0.97
Seattle, Washington	843	1914	922	0.151	1911	0.63
South Bend, Indiana	443	1907	521	0.337	1907	0.74
Spokane, Washington	681	1918	689	0.322	1907	0.85
Springfield, Illinois	423	1914	502	0.256	1910	0.83
Springfield, Massachusetts	326	1925	336	0.164	1905	0.99
Springfield, Ohio	912	1922	991	0.098	1930	0.47
St. Louis, Missouri	1001	1908	1080	0.214	1898	0.9
Stockton, California	178	1919	257	0.154	1917	0.81
Syracuse, New York	633	1917	686	0.098	1913	0.36
Tacoma, Washington	319	1910	341	0.233	1901	0.76
Terre Haute, Indiana	214	1924	237	0.129	1911	0.77
Titusville, Pennsylvania	188	1919	267	0.123	1923	0.74
Toledo, Ohio	765	1908	808	0.368	1901	0.84
Trenton, New Jersey	310	1921	315	0.219	1905	0.75

Location	Obs. max. (km)	Year obs.	Theor. max. (km)	<i>b</i> -value	Inflection year	<i>R</i> ²
Uniontown, Pennsylvania	196	1908	275	0.239	1914	0.56
Utica, New York	209	1917	211	0.357	1902	0.89
Washington, D. C	687	1918	766	0.121	1903	0.89
Waterloo, Iowa	229	1917	240	0.252	1907	0.87
Wheeling, West Virginia	277	1917	290	0.217	1903	0.88
Wichita, Kansas	176	1924	220	0.128	1915	0.85
Wilkes-Barre, Pennsylvania	253	1921	332	0.062	1910	0.86
Wilmington, Delaware	252	1924	257	0.14	1908	0.59
Worcester, Massachusetts	483	1917	539	0.144	1904	0.91
Youngstown, Ohio	576	1914	650	0.274	1907	0.96



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SUPPLEMENTARY MATERIALS

Supplemental Information (SI)

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