How New York City Residents Diminished Trash*

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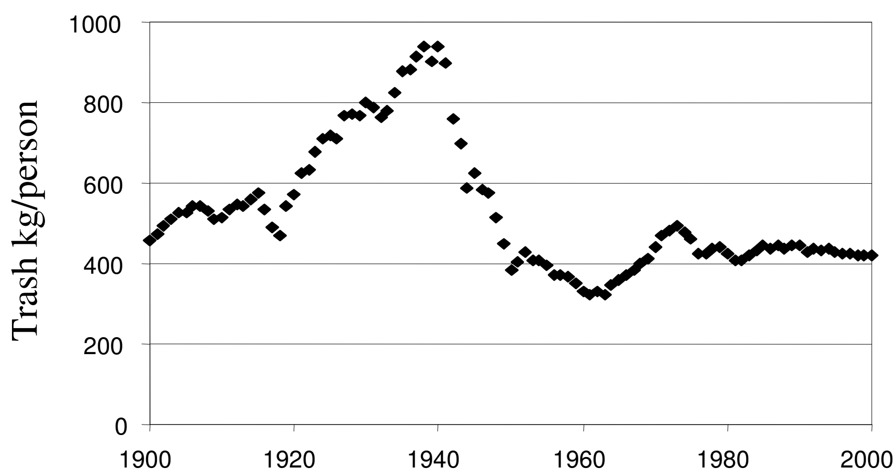
In 2002, *Nature* called attention to a surprising trend. "Recycling campaigners and environmental groups often quote alarming statistics on how much waste one person produces each year. But a comprehensive report [by Walsh] on rubbish collected in New York City throughout the twentieth century claims that the figure has dropped dramatically, from its peak in the 1940s" (Powell 2002). Although others studied trash disposal at a single time, Walsh (2002) analyzed the trend of residential trash recorded in New York City during the full 20th century, probably the most comprehensive records of any U.S. city.

How did affluence, consumption and technology produce the surprising trend of per capita trash (below), and then how did the number of people multiplied by per capita trash in turn change the City's total residential trash?



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* A supplement to Waggoner, P.E., and Ausubel, J.H. 2002. A framework for sustainability science: A renovated IPAT identity. Proc. National Acad. Sci. (US) 99:7860-7865. http://phe.rockefeller.edu/ImPACT/. Four other supplements examine "Do Consumers' Behavior and Producers' Efficiency Move in Consistent Patterns?", "Air Travel -- the Example of Materialization", "New Ways to Visualize the ImPACT Identity and Its Forces", and "Sustainability as a Journey on a Plane to Richer and Cleaner".

Decomposing trash to see the levers that lift it

The ImPACT identity* provides the means for identifying the levers changing environmental impact and visualizing the journey to sustainability, quantitatively. Let

P = population,

A = income, as GDP per person,

C = consumers' behavior, as kg product used per GDP, and

T = efficiency, as kg trash per kg product used. Then

$I_m = P \times A \times C \times T$ tons of trash from the city.

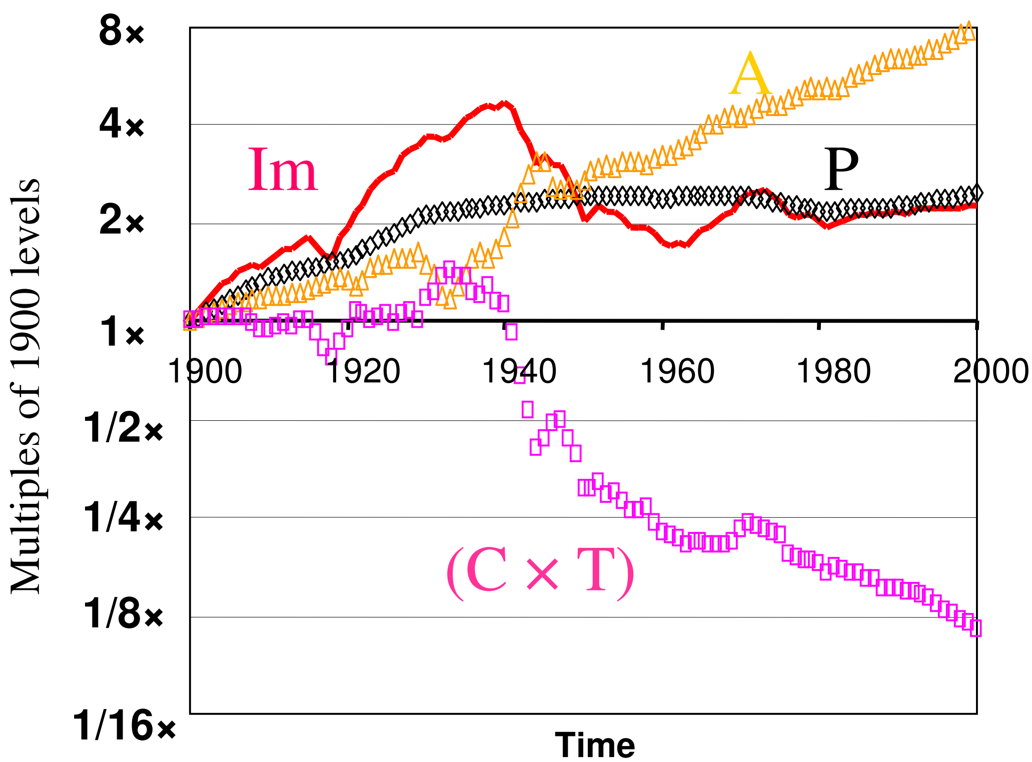
Sometimes C is called *intensity of use*, A *affluence* and T *technology*. We call decreasing C, *dematerialization*.

Walsh reported P population and ($A \times C \times T$) per capita trash. Although we do not know the three separate leverages A, C, and T, we can nevertheless make progress. First we approximate A with U.S. per capita GDP, which is a reasonable approximation so long as we focus on change rather than absolute value. Ideally, values of C consumption per GDP would be available. And values of T trash per consumption would be at hand. Since, however, separate C and T are unavailable, we must be content with the combined ($C \times T$) of trash per GDP.

The trends with time of leverage and trash

Re-defining leverages *P*, *A* and (*C* × *T*) as the logarithms of number of persons, dollars per person, and kilograms of trash per dollar makes their net equal the logarithm of the City's I_m tons of trash. So the net of the century-long trends marked in multiples of the 1900 levels of *P*, *A* and (*C* × *T*) on the chart below equals the trend of I_m.

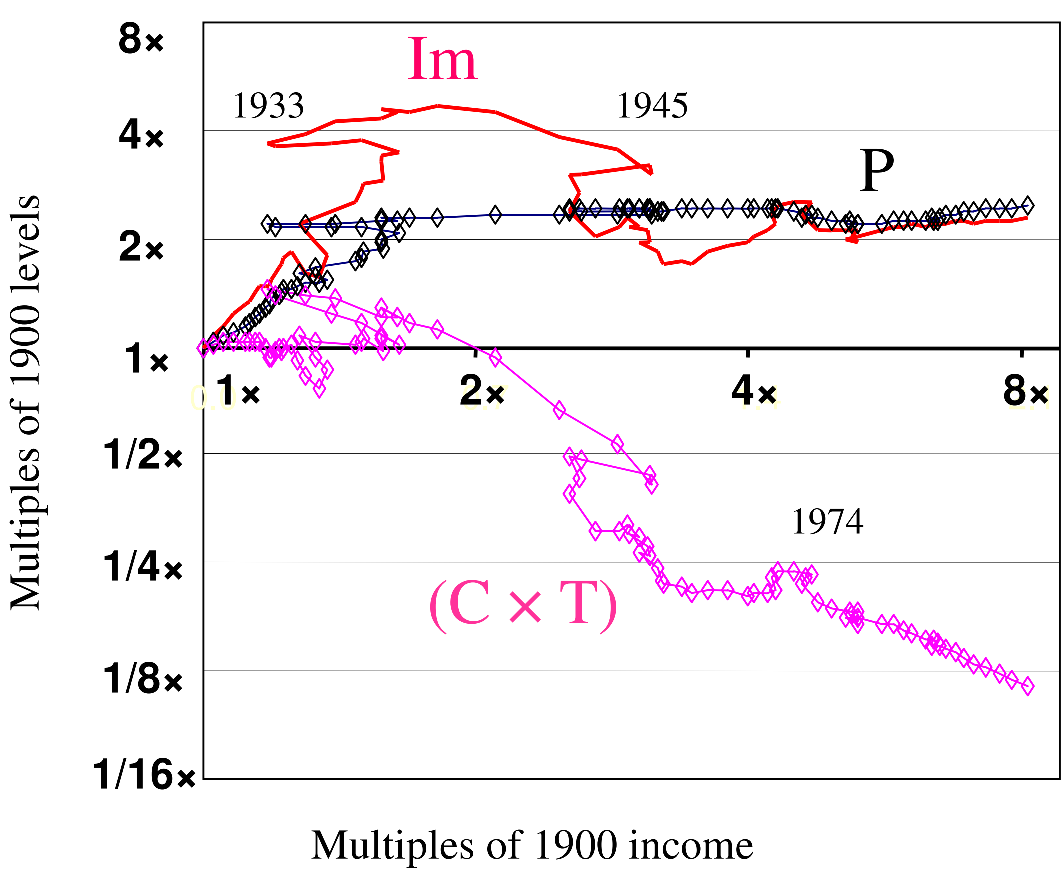
As time passed, *P* population rose and leveled at somewhat more than 2 × the 1900 population. Golden *A* income rose more, 8 × despite its falls around 1930 and 1950. Pink (*C* × *T*) trash per GDP holds the surprise: About 1940 trash plummeted as coal and the attendant ashes phased out. Then (*C* × *T*) continued to decline, showing a dematerialization of trash through the years since 1940. By the end of the century, the residents of the City discarded only 1/8 × as much (*C* × *T*) trash per GDP as at the beginning in 1900. If we could separate *C* from *T*, we could learn how much conservative consumption—such as fewer purchases and less overheating of residences—as distinct from technology in the form of lighter packages and more efficient furnaces countered rising income for the past four decades.



Navigating the Sustainability Plane

The chart below maps the same levers *P*, *A*, and ($C \times T$) and impact I_m—but the abscissa has changed from time to income. Where graphs of impact vs. income rise and then decline, the World Bank and others have labeled them Environmental Kuznets Curves. Because the Bruntland commission gave sustainability two dimensions, well being and environmental impact, we have called the chart below, the sustainability plane. Communities or nations "navigate the sustainability plane", hoping to travel east or right to higher income while steering south or down to less environmental impact. The red route of the City's I_m impact shows how it navigated the sustainability plane.

On the sustainability plane with longitude or abscissa being log (*A* income), the *P* population lever and the combined sustainability levers *C* and *T* steer I_m as people seek their goal of greater income. On the time course in the previous chart, boom and depression raised and lowered *A* income, but on the sustainability plane below, they levered *P* and ($C \times T$) east and west. On the coordinates of log (leverage or impact) vs. log (income), slope or heading equals income elasticity, and because income simply rises diagonally at a slope of 1 on the sustainability plane, we omitted *A* from the chart.



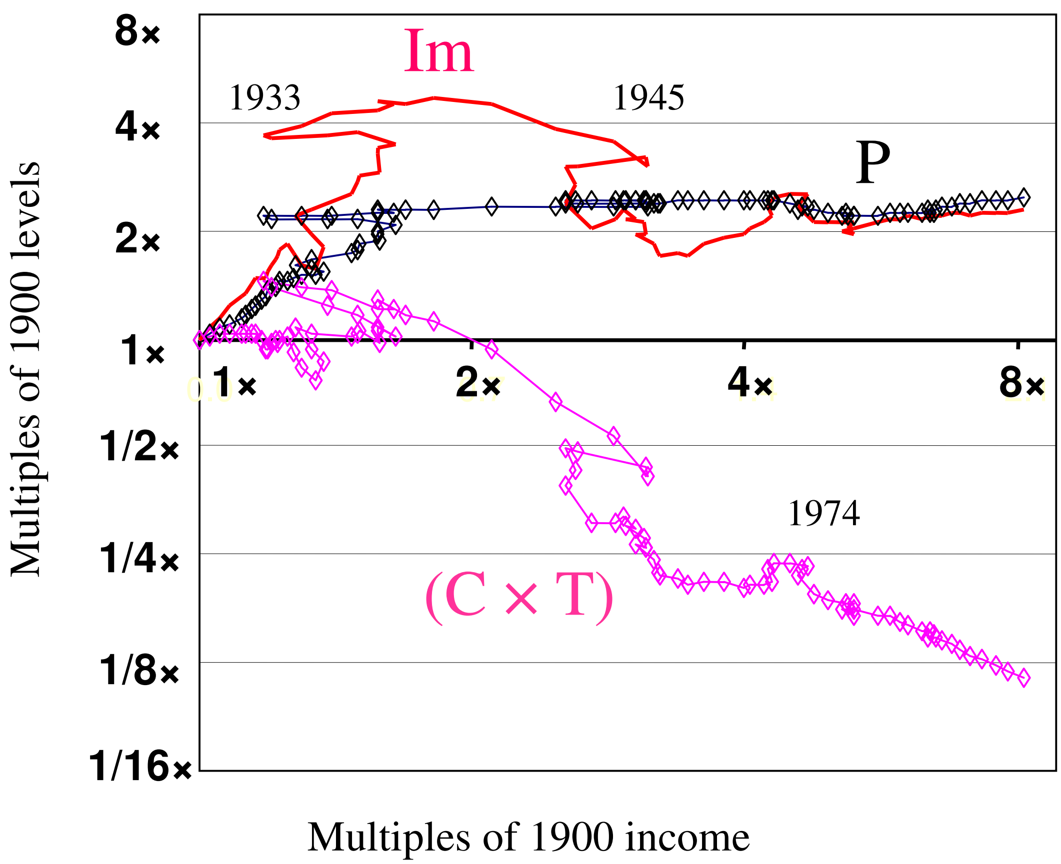
Navigating the Sustainability Plane (Concluded)

The previous chart is repeated below for the reader's convenience.

From 1900 to 1930 as more income carried New York City's route east on the plane, P population multiplied about 2×. Then as the Great Depression carried the route west, P leveled. Afterwards, despite the 4× increase of income during the rest of the century, population continued level.

On the chart, the behavior of pink ($C \times T$) or trash per GDP stands out. Until the Great Depression headed the route west on the sustainability plane, ($C \times T$) merely fluctuated. The phasing out of coal in the City combined with income improving east from, say, 2× to 3× the 1900 level, however, did finally cut ($C \times T$) trash per GDP. Less ash cutting per capita trash is no surprise. But, the continued decline or dematerialization of ($C \times T$) for decades after ash had nearly disappeared from residential trash and income grew to 8× its 1900 level is a surprise.

The halving of the City's trash from the maximum I_m when income was 1.5× the 1900 level to an income more than 8× the 1900 level shows a navigation of the sustainability plane that merits the name of Environmental Kuznets Curve.



In the Future

In 1992 the World Bank named an arc of rising and falling impact as income rose, the Environmental Kuznets Curve. The Curve is, of course, navigation first northeast and then southeast on the sustainability plane. The Bank's exemplar was urban concentration of sulfur dioxide. Later industrial ecologists found arcs traced by the *intensity of use* as income increased, but intensity is use per income and not impact. In the Bank's chart of municipal waste, for example, waste per capita increased relentlessly as income increased. Because a Kuznets Curve for a communal impact such as the City's *tons* of residential trash is uncommon, one must ask if its success can continue in the future.

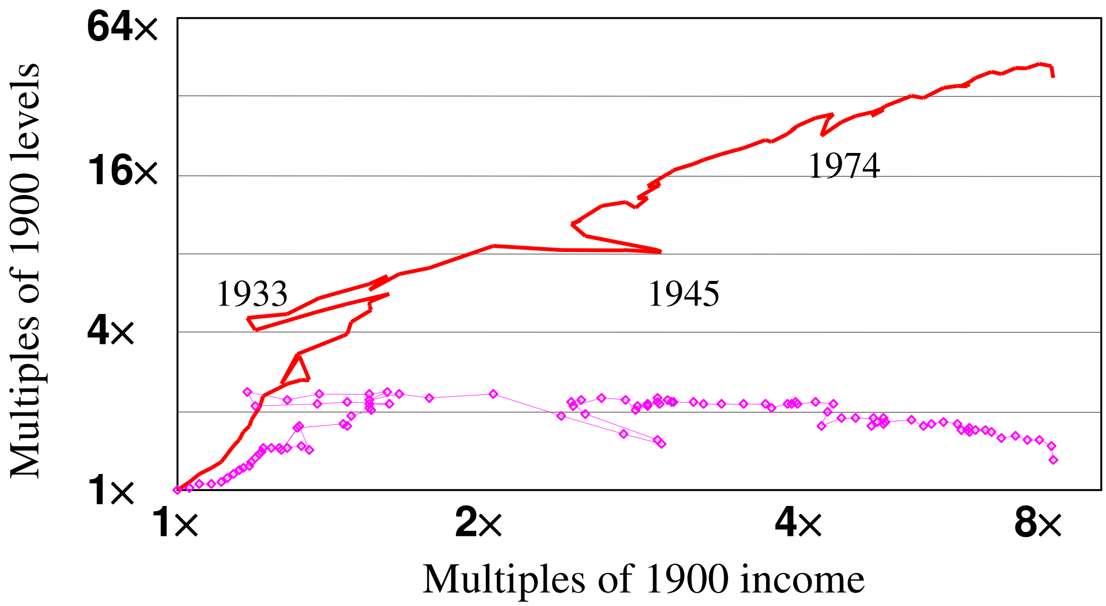
The composition of the trash holds clues. During the first half century, cutting ash from 80% of all trash in 1900 to 43% in 1939, and on to 2% in 1989 deserves much of the credit for steering a more southerly trip on the sustainability plane. The changing composition of trash from 1971 to 1989 reported by Walsh provides clues to how the residents might cut their steady 400 kg/ca/yr or the steady city-wide 3 million tons of trash. Metal plus glass and paper stand out among the components of the trash. Metal and glass declined from 34 to 11%, likely because plastics and aluminum diverted by a beverage container deposit was excluded from the reported trash. This substantial success contributed to the victory of declining $(C \times T)$.

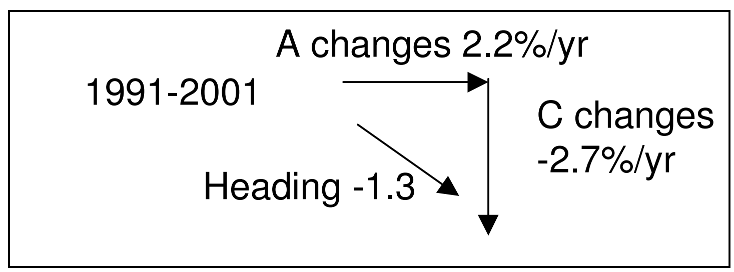
The paper content of the trash, however, continued about 34%. Although the City recycles about 40% of this waste paper, recycling does not affect reported trash. The reported trash *includes* recycled materials collected. A consumer returning metal and glass cuts reported trash, but the city picking up and recycling paper does not. Recycling may conserve trees in forests and space in dumps but does not cut the cost of collecting paper for recycling, a cost that now threatens recycling.

The large paper component in trash plus the equivocal effect of recycling focus attention on using less paper. Because packaging and communication use roughly equal paper and paperboard, they present equal opportunities. In their thorough rethinking of paper consumption, Robins and Roberts did find examples of less use.

The consumption of paper is $(P \times A \times C)$. On the sustainability plane in the next slide, C for US paper use headed southeast from 1990 to 2000. *C's* decrease of –2.7%/yr divided by *A's* 2.2%/yr increase equals the heading of –1.3. The heading of paper use equals the sum of the headings of *P, A,* and *C,* and the heading of paper trash equals the sum of the *P, A, C* and *T* headings. Let the City have steady population and so a heading of 0 for *P*, *A's* defined heading of 1.0, the recent heading of –1.3 for *C* in the USA, and a small heading of, say, -0.1 for *T*. The consequent (0+1.0-1.3-0.1) heading would turn paper trash southeastward on the sustainability plane as income increased in the future.

The navigation of US paper and paperboard use on the sustainability plane, 1900 to 2001





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