About the effective speed of transport modes.
An Ivan Illich's concept revisited

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Abstract

The effective speed of transport takes into account not only journey time but also working time to pay for travel. Proposed 40 years ago by Ivan Illich, this concept is always presented as a radical criticism of the car, a symbol of industrial society, because from this point of view a driver would be slower than a cyclist. This paper starts by outlining the limitations of this argument, explains the determinants of effective speed and shows that the effective speed of drivers is now higher than those of cyclists except in urban areas. Finally, Illich's analysis does not call into question the interest of ever-increasing speed. To identify a more consistent argument, this paper ends with a cost-benefit analysis that takes into account the negative externalities of speed in order to determine an optimal speed.

Keywords speed – effective speed – optimal speed – cost-benefit analysis

0. Introduction

In the early 70's, Ivan Illich, a leading critic of industrial society, popularized the idea that, taking into account not only journey time but also working time to pay for travel, a driver is ultimately much slower than a cyclist. This is what others have called the "effective speed" (or "generalized speed" in French, in reference to the concept of generalized cost). Despite the virulence of this criticism, it was never really the subject of debate and remains confined to the automobile opponents.

This paper seeks first to explain the reasons for this lack of debate and outlines the known limits of this criticism (Section 1). It then sets out, for the first time, a mathematical formalization of effective speed (Section 2) and shows that the driver effective speed is always increasing and rises above that of cyclists (Section 3). Finally a classic cost-benefit analysis of speed demonstrates that an optimal speed necessarily exists, opening the way for a renewed and coherent criticism of speed (Section 4).

1. State of knowledge

There is very little mention here because, despite a lot of French, English and German research on the subject, no academic work seems to have been produced directly on this subject, even if references to Illich's argument are not uncommon when the question of speed is discussed. However, as we shall see, this argument is open to serious objection. In fact, only a few cycling promoters have clung to this analysis and tried to enhance it. Let's start by looking at the background to the debate.

1.1. Origin of the concept

40 years ago, Jean-Pierre Dupuy, an engineer from the famous *Ecole polytechnique* (Paris), philosopher of science, and Illich's friend showed for the first time that "the effective speed of the car is usually less than that of the bicycle" and concluded: "Far from being an instrument for saving time, the automobile is, in this light, a time consuming monster." (Appendix of the French edition of *Energy and equity*, published in 1975 and reprint in 2003, p. 433). He explained his calculation (our own translation):

> "It is possible to estimate all annual possession and use costs of an automobile (…). These expenses are converted into time by dividing them by hourly income: this time is the working time necessary to acquire and use a car. It is then added to the journey time. (…) Finally we need to add another aspect of car use time: time spent on vehicle maintenance, time lost in traffic, time spent buying gasoline and other accessories, time spent in hospital, time lost in incidents, etc. The total time thus obtained, taken in conjunction with annual mileage, provides the effective speed.
> The following results [see Table 1] have been calculated for different socio-professional categories, different communes of residence, and different vehicle models, including the bicycle (the performance of the latter is obviously calculated on the same principle). The data relates to the year 1967." (Dupuy, 1975, pp. 433-434. See also Debouverie and Dupuy, 1974; Dupuy and Robert, 1976)

Table 1. Effective speed in km/h, according to J.-P. Dupuy (1975)

Socio-professional category	Bicycle	Citroën 2CV [economy car]	Simca 1301 [average car]	Citroën DS21 [luxury car]
Senior executive (Paris)	14	14	14	12
Employee (middle-sized town)	13	12	10	08
Skilled worker (middle-sized town)	13	10	08	06
Farm worker (rural commune)	12	08	06	04

The idea was revived and popularized by I. Illich who gave it a global impact. He said:

> "the typical American male devotes more than 1,600 hours a year to his car. He sits in it while it goes and while it stands idling. He parks it and searches for it. He earns the money to put down on it and to meet the monthly instalments. He works to pay for petrol, tolls, insurance, taxes and tickets. He spends four of his sixteen waking hours on the road or gathering his resources for it. And this time does not take into account the time consumed by other activities dictated by transport: time spent in hospitals, traffic courts and garages, time spent watching automobile commercials or attending consumer education meetings to improve the quality of the next buy. The model American puts in 1,600 hours to get 7,500 miles: less than five miles per hour" (Illich, 1973, pp. 18-19).

This result is pretty staggering because it seems to undermine the whole interest of using an automobile or, more specifically, travelling faster by using it. This is, no doubt, the most outstanding example of the Illich's criticism of industrial society. The analysts most critical of contemporary society never fail to cite his work (Gorz, 1973; Robert, 1980; Latouche, 2004…).

1.2. Some limits to this argument

However, this criticism had little impact on transport experts. It is true that, from the outset, J.-P. Dupuy (1975, p. 435) underlined the main flaw in his reasoning:

> "The calculation assumes the substitutability between journey time and working time. Of course, in the short term, this condition is not fulfilled. (…) The existence of constraints in the short-term gives a heavy weight to time savings that actual speed of journey allows. Despite its high cost, car travel may be preferable in the short term…"

(see also J.-P. Orfeuil, 2002, p. 7). Moreover, speed is not only a matter of time, journey or work, it is also a means of accessing more varied resources and this gives it considerable appeal (Hansen, 1959).

Another significant drawback of this analysis was also stressed by J.-P. Dupuy himself (1975, p. 435):

> "A second assumption behind the effective speed calculation is that 1 work hour = 1 journey hour, this time being seen as a cost." In fact: "Although the working time should be regarded as a constrained time as well as the journey time, there is in it a dimension of social integration, participation in the general activity of production, that there is not in journey time, which is a forced complement of the previous."

It is hard to imagine, in fact, spending hours on a bicycle – a mode of transport often more painful than the car – to save working time. Furthermore, at the same time, in early 1970's, J. Zahavi (1973) revealed the remarkable stability of the "travel time budget" over the long term: whatever the transport development, we always spend on average one hour a day travelling around. This conjecture remains broadly valid today. The trade-off between these two types of time actually seems remarkably limited.

Finally, his reasoning is based on an average for travel in rural as well as in urban areas, which masks large disparities. A driver who uses his car for long distance journeys, for example, would have an effective speed that is much higher than a cyclist.

In summary, the equivalence between travel time and working time is not obvious and it can appear absurd to use it. Yet the generalized cost concept – often used in traffic-forecasting models, both to determine the modal split and to assign traffic to transport infrastructure – is based on a similar calculation. It is assumed that the transport cost and transport time value can be aggregated and that users weigh up these two costs to choose the most efficient mode of transport (especially in price-time models to estimate the user's distribution between train and plane, between day and night trains, or between car and public transport), and to choose the best route (Wardrop's first principle). Similarly, although the driver's effective speed pales in comparison to the cyclist's effective speed, the driver's generalized cost is no better than the cyclist's generalized cost. For the same distance, it was usually much less expensive to travel by bike than by car in the late 60's. In short, criticisms of effective speed also apply to generalized cost.

1.3. Recent developments

In recent years, some heterodox authors have attempted to update and deepen the effective speed analysis (Dupuy, 2002; Kifer, 2002; Cheynet, 2003; Tranter, 2004 and 2012). And the reissue in French of the I. Illich's papers, after his death in 2002, has unearthed Dupuy's Appendix to the French edition of *Energy and Equity*.

Based on recent developments, we note first that J.-P. Dupuy (2001) reiterated (p. 36):

> "The French devoted [late 60's] an average of more than four hours a day to their car, whether ensconced in its cockpit on their way from one point to another, or buffing its chrome with their own hands, or, above all, working in factories or offices in order to obtain the resources necessary to its acquisition, use and maintenance. Returning recently to the data that we had gathered to carry out this calculation, I arrived at the conclusion that the present situation is no doubt worse than what it was twenty years ago.[1]
>
> If one divides the average number of miles traveled on all types of trips by the "generalized time" devoted to the car, one obtains something like a "generalized" speed [or effective speed]. This speed turns out to be a little more than four miles an hour [≈ 7 km/h], somewhat faster than a person walking at an ordinary pace, but considerably slower than a bicycle[2]."

In 2004, P. J. Tranter, an Australian researcher, produced a very well documented calculation, summarized in Table 2 below.

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[1] J.-P. Dupuy, "Le Travail contreproductif", *Le Monde de l'économie*, October 15, 1996.

[2] For the comparison to be perfectly accurate, one would have to take into account the effective speed of the bicycle on the road, not its average speed. However, since the cost of acquiring, using and maintaining this mode of transport is so modest, the difference between the two figures is minimal.

Table 2. Calculation of the effective speed, according to P. J. Tranter (2004)

	Monaro [luxury car]	Landcruiser Sahara [sport utility vehicle]	Falcon XT [average car]	Hyundai Getz [economy car]	Action bus [public transit]	Bicycle
Total annual transport costs (Australian $)	14 161	17 367	9 753	5 857	966	500
– Work hours to earn car expenses (h)	644	790	444	266	044	023
– Hours in vehicle (h)	333	333	333	333	600	750
– Other time for transport (walking to and from vehicle, cleaning car, repairs and servicing, buying fuel, checking tires…) (h)	051	051	051	051	060	055
Total hours devote to transport (h)	10280	11740	827	650	704	828
Average trip speed (km/h)	45	45	45	45	25	20
Effective speed (km/h)	14.6	12.8	18.1	23.1	21.3	18.1

The calculations are based on "Average Full-time Adult Total Earnings" of $40,100.60 after tax, and on an annual distance of 15,000 km.

Its results lead to an effective speed for cars much higher than that found by Dupuy and Illich, but Tranter does not draw any lessons from this difference. For him the main conclusion is:

> "The concept of 'effective speed' should be seen as one (of many) ways in which to highlight the ineffectiveness of private motor vehicles as a form of mass transport, as well as highlighting the superiority of public transport (and cycling)."

However, in the 45 years since 1967, the data year used by Dupuy, the situation has surely changed. It would also be useful to clarify the relationship between generalized cost, time and effective speed to better understand the parameters that determine these variables.

2. Formalization

Curiously, with the exception of A. Vaillant's short paper (2001), this formalization has never been performed. In fact, we cannot define effective speed without recalling at the same time the generalized cost and the generalized time (as already explained by Dupuy).

The generalized cost is the sum of the private costs of a journey (PC) and the time cost spent during the journey (TC). The first cost is the product of the distance travelled (d) by the kilometric cost per passenger (k)[3]. And the second is the product of the journey time from door to door (JT) by the transport time value often equated to the hourly wage (w).

The generalized cost can then be converted to spending time to get a "generalized journey time" (GT), defined as the quotient of the generalized cost (GC) by the hourly wage (w). The generalized time is broken down into a journey time (JT) and a working time to pay for the private journey cost (WT).

Finally, the ratio between the distance travelled (d) and the generalized time (GT) defines the effective speed (E). This differs from the average speed which is the ratio between the distance travelled (d) and the journey time (JT).

The relationships between the three concepts are as follows:

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[3] This cost includes "purchase or lease, insurance, registration and vehicle taxes, maintenance and repair, fuel, fuel taxes and oil, paid parking and tolls" (Litman, 2009).

$$GC = w \times GT = \frac{d \times w}{E} \qquad GT = \frac{GC}{w} = \frac{d}{E} \qquad E = \frac{d}{GT} = \frac{d \times w}{GC}$$

By performing a few simple calculations, it is possible to express these three concepts in four basic parameters – the average speed from door to door (s), the distance (d), the kilometric cost per passenger (k) and the hourly wage (w) – and to understand how they evolve with each of these parameters. Table 3 summarizes all of the results.

Table 3. Generalized cost, generalized time and effective speed

	Generalized cost	Generalized time	Effective speed
Definition	$GC = PC + TC$ $= (d \times k) + (w \times JT)$ $= d \times (k + \frac{w}{s})$	$GT = JT + WT = \frac{GC}{w}$ $= d \times \left(\frac{1}{s} + \frac{k}{w}\right)$	$E = \frac{d}{GT} = \frac{d \times w}{GC}$ $= \frac{1}{\frac{1}{s} + \frac{k}{w}}$
Consequences	$GC > PC$ $GC > TC$	$GT > JT$ $GT > WT$	$E < s$
When d ↑	GC ↑	GT ↑	E →
When w ↑	GC ↑	GT ↓	E ↑
When k ↑	GC ↑	GT ↑	E ↓
When s ↑	GC ↓	GT ↓	E ↑
When $s \to 0$	$TC \to \infty$ $GC \to \infty$	$JT \to \infty$ $GT \to \infty$	$E \to 0$
When $s \to \infty$	$TC \to 0$ $GC \to PC$	$JT \to 0$ $GT \to WT$	$E \to w/k$

with GC : generalized journey cost; GT : generalized journey time; E : effective speed
PC : private journey cost; JT : journey time
TC : time journey cost; WT : working time to pay for the private journey cost
and s : average speed (s = d / JT); k : kilometric cost per passenger
d : distance travelled; w : transport time value ≈ hourly wage

The definition of effective speed can be summarised as follows:

$$\boxed{E = \frac{1}{\frac{1}{s} + \frac{k}{w}}}$$

This means that the effective speed depends only on three parameters: the average speed, the hourly wage and the kilometric cost. In particular, it does not depend on the distance travelled, because the two components of the generalized journey time are proportional to the distance:

$$JT = \frac{d}{s} \quad \text{and} \quad WT = \frac{d \times k}{w}$$

3. Results

We shall now consider how the effective speed evolves according to these three parameters.

3.1. Average speed, effective speed, and effective speed limit

In the short run, when the user seeks to gain all the time allowed by the growth of the average speed without changing its destination, the effective speed increases, but less than proportionally.

$$E < s, \text{ because } s, k \text{ et } w > 0$$

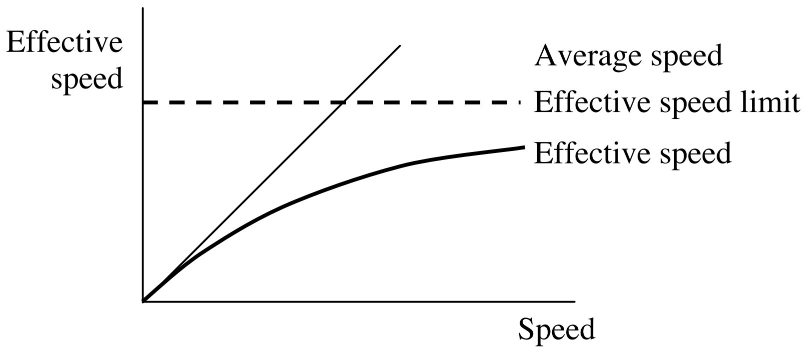
And the more the average speed grows, the more the effective speed deviates. Because, for a low-speed, the journey time is very high compared to the working time, and when the speed increases the journey time is reduced significantly and the working time becomes dominant. Therefore, the effective speed tends towards the ratio between hourly wage and kilometric cost, which is an unsurpassable effective speed limit (l).

$$\text{When } s \rightarrow \infty, E \rightarrow l = w/k$$

Today, if we consider that, in France, w = €13 per hour (source: INSEE – National Institute of Statistics and Economic Studies) and k = €0.25 per passenger-kilometre (Beauvais, 2012; see Box 1), then l = 52 km/h. The drivers cannot exceed this speed.

Finally, compared to the speed, the effective speed is a hyperbolic function, thus strictly increasing (Figure 1). Although the effective speed always increases more slowly than the speed (which many authors point out), it never ceases to grow (which they neglect to mention), for every distance travelled. Thus, higher car speed can always "save time", even if the effective speed gain is weak. It is only in relation to the bicycle in urban areas that using an automobile is a "waste of time".

Figure 1. Evolution of the effective speed in term of speed



However, this result is only valid in the short term, when the user does not change his destinations. In the long term, he prefers to enjoy the speed to increase the distance travelled and the number of accessible destinations. He may therefore reach a wider choice of jobs, shops, services, recreational sites and social contacts, thereby improving his satisfaction and his economic and social efficiency (Koenig, 1980).

The user can choose either to save time or to travel further, the result is the same: the speed is always seen as beneficial and the effective speed concept does not alter this conclusion.

Taking into account the negative externalities of transport in the private costs slightly reduces the effective speed (as emphasized Tranter, 2004). But again, it remains an increasing function of speed, because economists argue, often implicitly, and to simplify the calculations, these effects do not depend on speed, at least for small changes, but only on the traffic measured in vehicle-kilometre (Baumstark, 2003). This may be assumed, at most, for noise or pollution but not for accidents, nor congestion. Moreover, many other external effects depend heavily on speed, such as urban sprawl or social segregation, as we discuss below.

3.2. Kilometric cost, hourly wage and effective speed

The effective speed increases with the rate of hourly wage (or labour productivity) because the working time to pay for the journey is reduced. As such, all things being equal, wealthy people – drivers or cyclists – benefit from a high effective speed. And employees whose real wages rise during their working life can also access it gradually.

In contrast, the effective speed changes inversely with the kilometric cost or vehicle costs per kilometre per passenger. Thus, with equal incomes, those with powerful but expensive cars and therefore with a high kilometric cost have a lower effective speed (as already noticed by Dupuy and Tranter). And those with a lower income are forced to use inexpensive vehicles in order to benefit from an acceptable effective speed. But when the real price of vehicles, automotive services or fuel decreases, the effective speed increases.

Finally, higher wages coupled with lower kilometric costs increase the effective speed and its upper limit (w/k) in the same proportion.

3.3. Evolution of the effective speed since 45 years

Between 1967 (reference date of Dupuy's calculations) and today, what has been the evolution of the three parameters used in the calculation of the effective speed? Here is a rough appraisal for France.

1/ The average car speed is not well known, but it has increased by at least 30%. During the 70's, urban areas benefited from government subsidies to develop traffic plans (TEC, 1973). The national motorway network also grew from 1,000 km in 1967 to 11,500 km in 2010. Thus, in the Paris region, which accounts for more than 80% of French congestion (source: *Centre national d'information routière*), the average car speed increased by 12% between 1976 and 2001 (source: local transport surveys), and perhaps 20% in 45 years. In provincial towns, it is probably much higher, but the surveys do not measure it. According to national transport surveys, the average journey speed for all transport modes have increased from 19 km/h in 1982 to 25 km/h in 1994 and 26.5 km/h in 2008 (+39%).

2/ The hourly wage in constant Euros has grown by about 150%, because the annual average net wage in constant Euros has increased by 77% from 1967 to 2009 (source: INSEE) and working time has dropped by 29% (from 2,079 hours per year in 1967 to 1,476 in 2011, source: OECD).

3/ The kilometric cost per passenger in constant Euros has increased by about 30% (26% between 1970 and 2009, according to Beauvais, 2012, on the basis of INSEE data) because the real cost of vehicles has declined little but the real cost of maintenance and repair has increased strongly.

It follows that, in France, over 45 years, the driver effective speed has jumped by 60%, and the effective speed limit has doubled. The same probably applies in other developed countries. However, this trend has slowed sharply in recent years with weaker hourly wage growth, a rising kilometric cost with fuel price appreciation, and a decreasing average speed due to the introduction of an automatic speed control system, the slowdown in new infrastructures construction programs, and traffic calming policies in cities.

For the bike, the average speed has probably slightly increased with bicycle improvements and better cycling facilities. The cyclists' hourly wage has followed the same trend as that of drivers (+150%). And probably the kilometric cost too, but it is also better known and far superior than previously thought (see Box 1) – an increase of about 100%. This uncertainty is of little consequence, because for the cyclists, the share of the kilometric cost in the generalized cost is low (fifth to tenth), while for the driver, it is about half: slightly less in the country and slightly more in the city. Therefore, the cyclist effective speed has hardly changed (about +7%, or +15% if Papon's appraisal is contested).

In total, the effective speed which was, 45 years ago, less for the car than the bicycle, is now higher for the driver than the cyclist (see Table 6). This is confirmed by Tranter's calculations (2004). So, for J.-P. Dupuy, it was about 4 to 14 km/h by car and 15 km/h by bike, and it is now about 13 to 23 km/h for the car and 12 to 18 km/h for the bicycle, according to the assumptions used for the driver kilometric cost or the cyclist average speed. Table 6 shows the effective speed evolution and our own assumptions.

Table 6. Appraisal of the effective speed evolution, in France

			For the car			For the bike		
			1967	2012	Evolution	1967	2012	Evolution
Average speed	s	(km/h)	30.8	40.0	30%	14.4	15.0	4%
Average hourly wage	w	(€ 2012)	5.2	13.0	150%	5.2	13.0	150%
Kilometric cost	k	(€ 2012)	0.19	0.25	30%	*0.07	0.13	100%
Effective speed	E	(km/h)	14.4	22.6	101%	12.2	13.0	7%
Effective speed limit	l	(km/h)	27.0	52.0	92%	80.0	100.0	25%

1967: Dupuy's appraisal. 2012: our own appraisal. *Underestimated value.

In conclusion, this formalization clarifies the scope of Illich-Dupuy's criticism of speed. Their reasoning does not question the endless search for ever-greater speed, which is always beneficial in any case, in the short and long term. Worse, the driver effective speed is today most often higher than for the cyclist; the argument turns against the authors and justifies, 45 years later, in most cases, using the car instead of the bicycle. To keep up Illich-Dupuy's reasoning, it is possible to distinguish, on one hand, the suburban area and the countryside where the driver effective speed is always higher than those of the cyclist and, on the other hand, the urban area, where it is the opposite. This is why P. J. Tranter (2012) only studies the speed issue in cities.

Box 1. How to calculate the private transport costs

As regards cars, many authors use data provided by automobile clubs (e.g. the Royal Automobile Club cited by Tranter, 2004) for their calculations. But these data are of course overestimated, because it is in the interest of these lobbies to push up the numbers. It is preferable to divide the total household expenses for cars by the number of passenger-kilometres (e.g. as J.-M. Beauvais did recently using data from the *Commission des comptes des transports de la Nation*. Finally, the obtained cost is almost two times lower (see Table 4). And the calculation must be achieved per passenger-kilometre and not per vehicle-kilometre.

Table 4. Kilometric costs of drivers (in €/P-km 2009)

Marginal expenses	(fuel, paid parking and tolls)	0.0705
Variable expenses	(marginal expenses + oil, parts and accessories, maintenance and repair, other services)	0.1696
Total expenses	(variable expenses + insurance, purchase of new and second-hand cars)	0.2407

Source: Beauvais, 2012.

As regards bicycles, in 2002, F. Papon's meta-analysis concludes that, for an occasional or average cyclist, the depreciation charges are high, but other costs are negligible. For a regular cyclist, the contrary is the case (see Table 5). On average, the cyclist kilometric cost is €0.12 in 2000, and about €0.13 in 2012.

Table 5. Kilometric costs of cyclists (in €/km 2000)

	Occasional or average cyclist	Regular cyclist (2000 km/year)
Bike depreciation, theft or lock	0.12	0.012
Clothing and accessories	-	0.028
Maintenance	-	0.024
Maintenance time	-	0.024
Food	-	0.024
Total	0.12	0.112

Source: Papon, 2002.

4. Towards a cost-benefit analysis of speed

To establish a more coherent discourse on speed, we need to consider its costs and benefits more fully. This is exactly the concept embodied in "optimal speed", used for the past 30 years by some authors, but mostly for intercity traffic on the road network (e.g. Jondrow *et alii*, 1983; and many other authors).

4.1. From the existence of an optimal speed

On reflection, it is impossible to say that an infinite rise in motor vehicle speed is always favourable. Our aim here is not to provide absolute proof of this argument, but to sketch out a line of research.

First, from a technical viewpoint, all negative externalities depend on speed, often significantly. On the one hand, they all increase beyond 30 to 60 km/h. This is true not only for the most studied nuisances - noise, pollution, accidents and congestion (OECD, ECMT, 2007) - but also for less studied nuisances, such as severance effects, land use and urban sprawl, social segregation, or the disqualification of non-motorized modes (Héran, 2000). On the other hand, certain nuisances are increasing, when the speed is very low, such as pollution, congestion, or space consumption. This justifies the use of walking and cycling at this pace. There is therefore necessarily an optimal speed that minimizes motor vehicle nuisances, which differs depending on the number of people concerned, that is, in the city or in the countryside.

Second, from an economic viewpoint, monetary benefits in terms of time savings in the short term (which is assumed to be equivalent to accessibility gains over the longer term) are offset by fuel costs and nuisances (accidents, noise and pollution) that increase more than proportionally at high speed. For example, using this reasoning and calculations based on marginal costs, L. Carnis (2004) managed, quite convincingly, to determine an “optimal speed for light vehicles on the French intercity network” (excluding motorways), which is of the order of 84 km/h, close to the speed limits in force (90 km/h on roads outside the agglomeration and 110 km/h on dual carriageways), justifying at the same time the road safety policy and pollution reduction.

However, such work is more difficult in urban areas where the situation is complex and transport pollution much higher and certainly more varied (see Cameron’s attempt, 2004). In this environment, speed impacts such as noise, severance effects, social segregation and urban sprawl cannot be considered negligible, as is the case in the countryside.

Finally, the benefits of increased speed can themselves be criticized for at least five reasons.

1/ It is worth recalling that speed does not increase the number of trips and opportunities for interaction, which remain quite steady in the long term (Zahavi, 1973), but only the trip length and the choice of destinations. In addition, a far distance is no more useful than a near distance, because it only counts the activity performed at destination.

2/ It is possible to seriously question the need to further expand the choice of consumers, people looking for work, or firms looking for employees, as advocated by the standard theory (Koenig, 1980). Reducing the balance between supply and demand in various markets to a more or less extensive choice of goods or services is, on reflection, somewhat simplistic. Today, in most cases, the choice is already considerable and its enlargement no longer as decisive. We entered a society where “hyperchoice” is not without adverse effects: it is difficult to navigate this universe, leading people to renounce choice, or even consumption (Schwartz, 2004). Other aspects clearly play a more crucial role: the quality of goods and services and the relationship built between suppliers and demanders.

3/ Human population density (inhabitants + jobs per hectare) is a powerful way to increase accessibility. In a given time, despite journey speeds much higher in suburban areas than city centres, people in the suburbs can access fewer destinations than people or employees in the centre. If you enjoy coming into contact with a wide variety of people, it is always more interesting to live and work in densely populated areas. And this is why so many households and firms continue to settle in or near the centre, despite slow journeys and high housing and real estate costs.

4/ In this regard, the argument that speed allows you to escape pressure on land looks a lot weaker when one realizes that the total budget spent on housing and journeys hardly varies between areas near the centre and the outer suburbs, nor indeed the housing surface available per person (Orfeuil and Polacchini, 1999, paper updated in 2005 with the same results).

5/ Major transport infrastructure improves distant accessibility, but at the expense of close accessibility, because of multiple severance effects in a given territory. It is often easier and less dangerous to pass through the city by car than to cross a thoroughfare by foot or by bike. This is "the paradox of the link which cuts" (Héran, 2011, Chapter 6).

There is therefore a range of optimal speeds according to the individuals, types of networks, and the urban and rural areas, to reconcile the "negative externalities of speed" and its benefits in term of accessibility.

4.2. Social effective speed and optimal speed

It is theoretically possible to internalize the negative externalities of speed in the private cost, and obtain a "social cost" integrated in a "social generalized cost" and a "social effective speed". Thus, in terms of speed, the social generalized cost has a minimum and the social effective speed a maximum corresponding, for the car, to the optimal speed (which, to be more precise, should be called the "optimal social effective speed").

For the bicycle, there is no optimal speed (today, in France, w/k = 13/0.13 = 100 km/h!), rather a limited speed uniquely linked to the cyclist's physiological limitations. In other words, for a cyclist, it is always better to cycle as fast as possible, as already explained by F. Papon (2002).

From a formal point of view, the social effective speed ($\overline{E}$) depends on the "social kilometric cost" ($\overline{k}$), which incorporates the negative impacts of speed. It is not possible to specify the relationship between $\overline{k}$ and the speed s without significant research. However, it could be as follows:

$$\overline{k} = \frac{a}{s} + bs + cs^2$$

so as to integrate the inversely proportional, proportional and more than proportional impacts of the speed, with parameters (a, b and c) to be determined. Then:

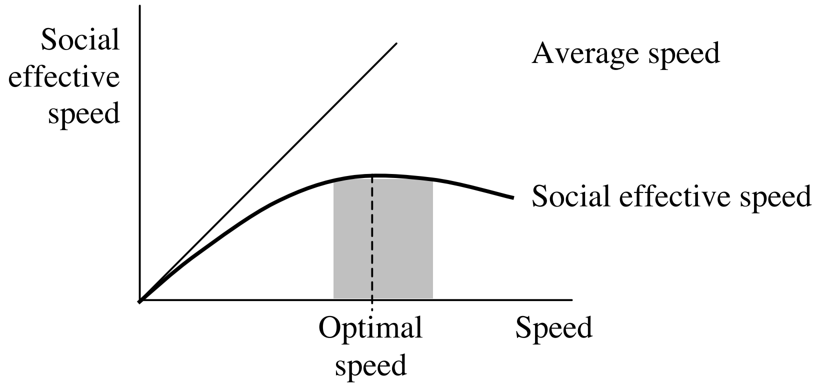
$$\overline{E} = \frac{1}{\frac{1}{s} + \frac{\overline{k}}{w}}$$

And the optimal speed is reached when the first derivative of the social effective speed relative to the speed is equal to zero:

$$\frac{\partial \overline{E}}{\partial s} = 0$$

Figure 2 shows this formalization.

Figure 2. Evolution of the social effective speed in term of speed



In practice, it is already not easy to determine an optimal speed on a road network in the countryside. In urban areas, it will be more difficult if not impossible, for many reasons. Firstly, the impact of speed on certain nuisances is still poorly understood. Nobody knows precisely how to measure its impact on social segregation, even if it is undeniable (Mignot and Rosales Montano, 2006). Even the speed–pollution relationship is still controversial and one must distinguish between each pollutant. Secondly, the streets are already more or less hierarchical (arterial, collector and local): it's impossible to aggregate these various cases. Thirdly, it is not certain that the optimal speed is significantly lower than speeds currently practiced. Nonetheless, it is likely a calculation error would have a slight impact on the optimum (grey area in Figure 2). This is precisely why traffic calming measures do not have a major impact on the economic efficiency of cities. Established "calmed cities" (Amsterdam, Copenhagen, Hamburg, Berlin, Zürich…) are not in decline. $$

5. Concluding remarks and prospects

Reasoning in terms of general speed has the great merit of revealing the huge production detour imposed by cars used to "save time", as rightly underlined by J.-P. Dupuy, and forces us to question the economic and social relevance of this detour so destructive to our environment, which is, in short, counterproductive (Dupuy, 2002).

But it is important to recognise that the automobile allows people, more than ever, to save time, especially compared to the bicycle. The existence of an effective speed limit does not affect this result, contrary to what is generally stated. It is only in urban areas that the effective speed is lower for drivers than for cyclists. Thus, the radical criticism is not about speed, but industrial society.

However, speed as such does indeed pose a social problem: although its benefits are undeniable, if often overestimated, it also causes, beyond a certain threshold, many nuisances with exponential and underestimated impacts (noise, pollution, space consumption, severance effects, social segregation, etc.). Today a more in-depth reflection on the positive and negative effects of speed is essential. It is possible to show, at least roughly, using economic calculation, that there is probably, for urban and intercity travel, by type of networks, an optimal speed compatible with the development of economic and social activities, leaving more space for autogenous and environmentally friendly modes of transport and the conservation of a better quality of life (G. Dupuy 1999).

In the future, the driver effective speed will decline probably for many reasons (Tranter, 2004 and 2012). The kilometric cost of cars should rise with fuel price appreciation. The average hourly wage could decrease with the crisis. And the progressive internalisation of the negative externalities of speed may slow down drivers. On the contrary, the cyclist effective speed should increase. The improvement of bicycle facilities which do not require the cyclist to stop and the wider use of electrically assisted cycles will raise the speed of cyclists, as on the "cycle super highways" currently built in The Netherlands and Copenhagen. Illich and Dupuy will be right once again.

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