Secrets of speed: what really makes a bike fast?

Part 1: weight savings

BY CHARLES HOWE

The evolution of bicycle design in pursuit of speed has been inexorable, with improved aerodynamics and reduced weight being the two primary approaches taken. In the latter case, the last ten years have seen the ever-widening use of titanium alloys and carbon fiber. These materials are most effective on uphill terrain, where weight directly accounts for over 80% of the energy expended by a 68 kg recreational rider on grades of 4.5% or more, increasing proportionately with the slope of the road.

The benefit of weight reductions can quantified by an equation of motion for cycling that has been validated in numerous peer-review studies by wind tunnel, tow rope/dynamometer, and coast-down tests. This expression was used to plot the two graphs below, under conditions of still air, sea-level barometric pressure, and a temperature of 24° C. To use them, you must know (or have a reasonable estimate of) the gradient of the hill being climbed and your power output in Watts per kilogram of body mass (both assumed constant), as well as the length of the hill in kilometers (miles × 0.6214 = km).

Begin by selecting the grade % of the hill on the horizontal axis and trace a straight line upward, parallel to the vertical axis, until you come to the line representing the power output that is right for you (estimate if it falls in between two lines). Then, read where this point intersects the vertical axis by moving to the left at a 90° angle to the line you've drawn. Multiply this number by the length of the hill in km and the amount of mass saved in kilograms (lbs × 0.4536 = kg). The result indicates either the time you will save in seconds (Figure 1), or the distance gain in meters (Figure 2).

Both graphs are based on a 2.5% reduction from an initial rider/equipment mass of 80 kg (176 lb), but are accurate to $\pm$0.14 s/kg/km (1.7 m/km/kg) where the total mass is initially 70-90 kg, the reduction is 5% or less, and power output is greater than 1.2 W/kg.

Here's a concrete example using a total mass of 80 kg and a power output of 247 Watts: a pair of superlight brake calipers with a mass 215 grams less than your present set will save you 0.7 seconds per lap on at the Chippewa Creek Road Race, which is held on a hilly 4.08-mile circuit in the Brecksville Metropark. The performance gain is virtually insignificant, and that's the good news. The bad news? They set you back $400.

Of course, many factors determine climbing performance, and shedding even a few pounds won't turn you into Levi Leipheimer overnight. Fitness, technique, the tempo and cadence (i.e., gear) you select, even the condition and fit of your bicycle must all be maximized first. Retrofitting with expensive lightweight parts should never be used as a substitute for doing so, in fact, it should be given the lowest priority, and titanium jewelry isn't the only way to lighten up: a frame pump and small seat pack containing innertube and several tools can total over 700 grams, while two half-full water bottles come to about 900 grams.

Furthermore, lightness isn't the only criterion by which a component is judged; strength, durability, comfort, and overall performance must also be considered. New parts should always be thoroughly tested in training and simulated racing situations before use in actual competition.

Finally, these illustrations consider only the case of uphill cycling, but there are neither many "pure" hillclimbs, nor road races ending with a large elevation gain (i.e., mountaintop finish); most events take place on a circuit, where excess weight becomes an *aiding*, rather than resisting force on the downhill sections, so there is actually a *penalty* to weight reductions when descending. The overwhelming determinant of downhill speed, however, is the ratio of weight to aerodynamic drag, so the time loss is largely blunted as speed increases. In addition, bike-handling skill, confidence, and familiarity with the course all affect descending performance.

Thus, lightweight components are expensive, they are effective in only a couple specialized situations, and the benefit is rather limited. Why then are ‘weight weenies’ only on the endangered species list, and not yet extinct? A number of factors can be identified:

1. ease of measurement – accurate component weight can even be obtained using a postal scale, as contrasted with determining aerodynamic improvements, which must be determined either by wind-tunnel testing (costing $500+ per hour at one of the few facilities around the country), or else from field-testing with a power-measuring system (a method of limited accuracy)
2. perceptual assessment – relatively small weight reductions can be sensed
3. the benefit of weight reductions is nearly cumulative (reductions aerodynamic drag are not), and can be totaled easily
4. the international (“metric”) system: e.g., 100 grams is only 3.5 ounces (about the same as a Clif Bar and pack of Gu), or less than a ¼ lb, but sounds much more impressive than its Imperial equivalent
5. marketing hype fosters the impression that lightweight bicycles and components – like a lean, chiseled body – are more efficient and desirable
6. a general lack of knowledge and awareness of the dynamics of cycling

More sophisticated riders, however, know to concentrate their efforts on reducing aerodynamic drag, in all situations except the rare hillclimb with a steep gradient and significant elevation gain.

Next month: how better aerodynamics make a bike faster.

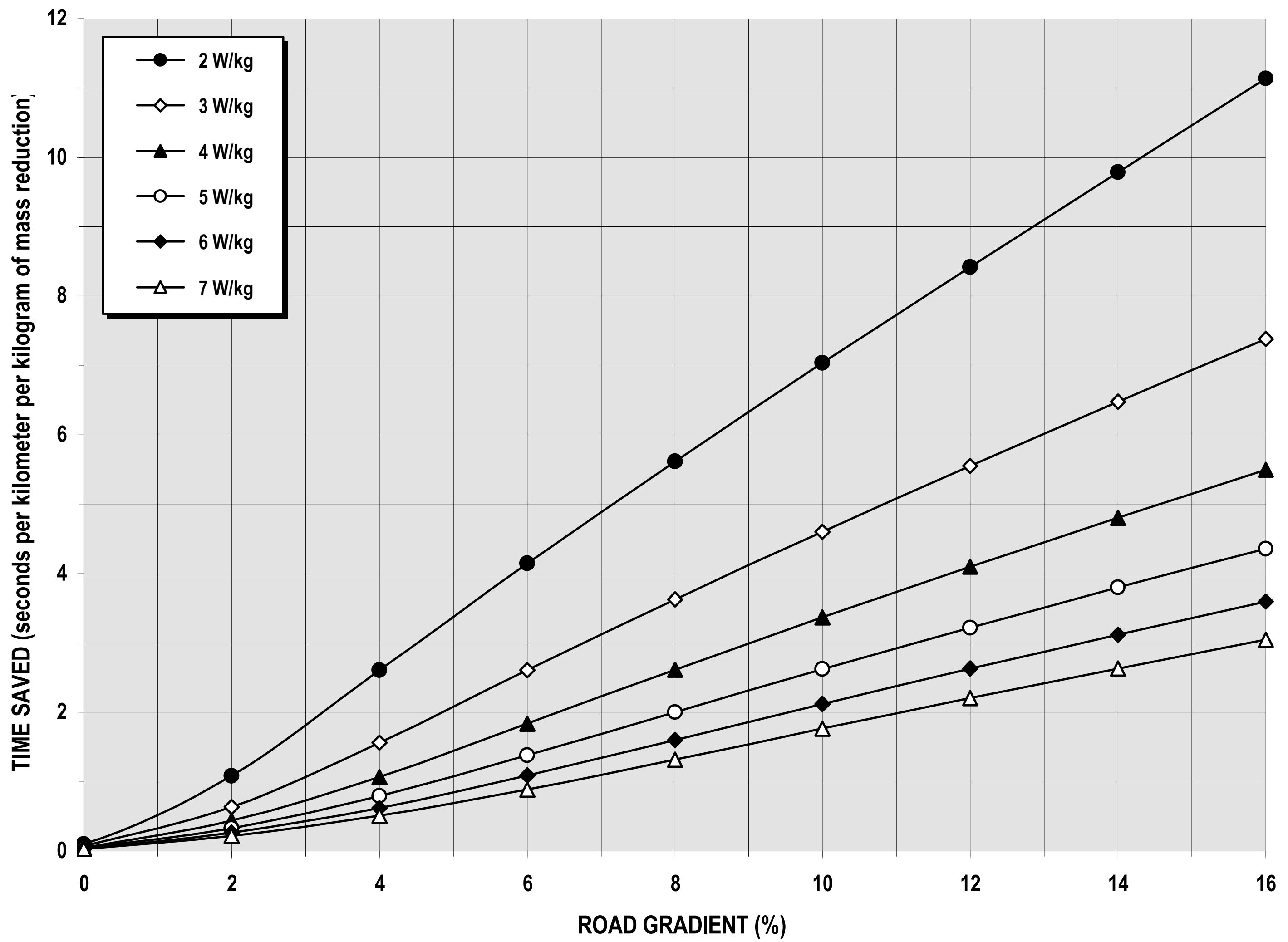

Figure 1. Time savings relative to mass reduction and distance traveled, as a function of uphill road gradient.

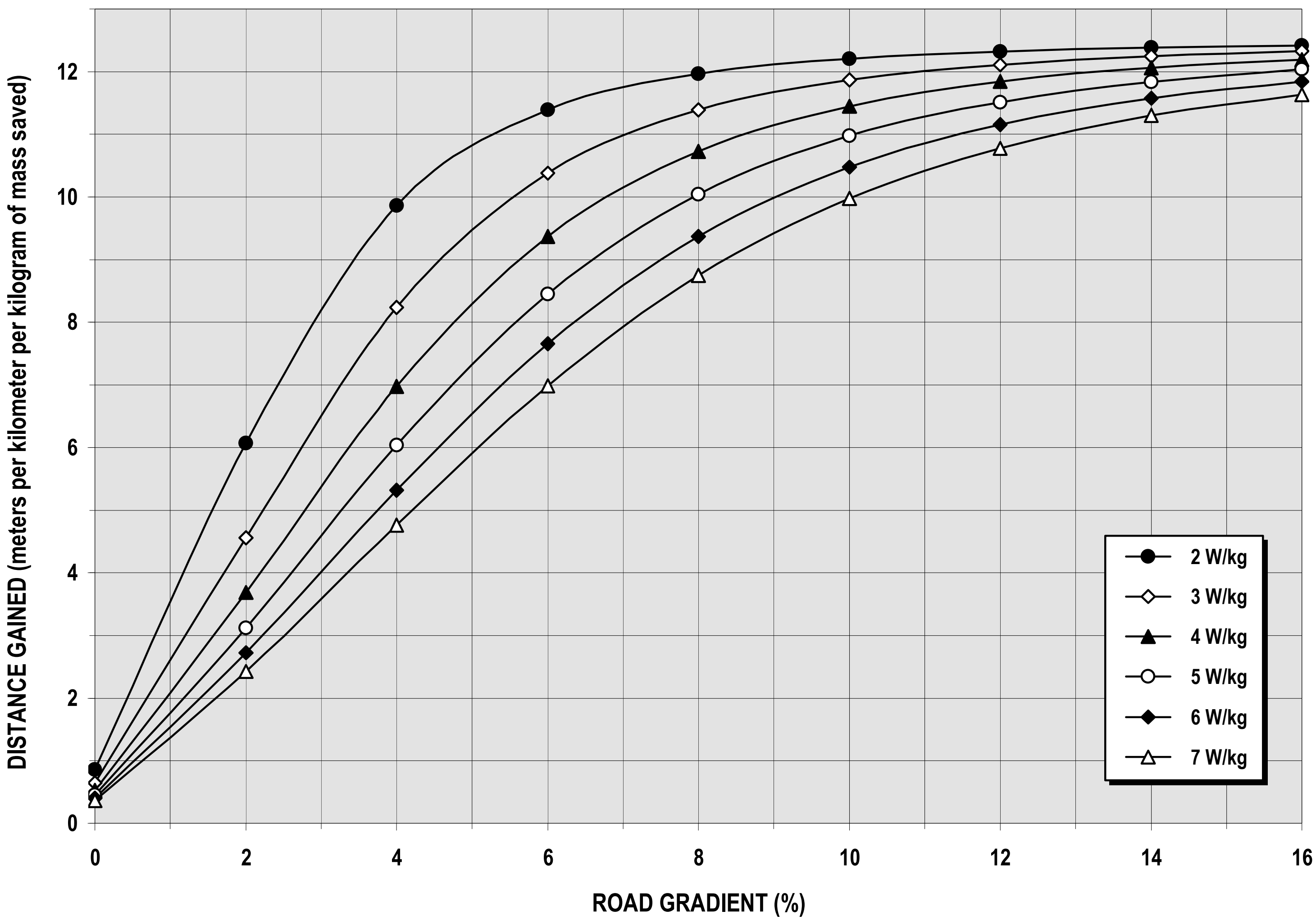

Figure 2. Distance gain relative to mass reduction and distance traveled, as a function of uphill road gradient.

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