ERC Symposium
on

Reducing Fuel Consumption: Solutions & Prospects

University of Wisconsin
Madison
June 10, 2009

Technology and Policy Choices for Personal Mobility

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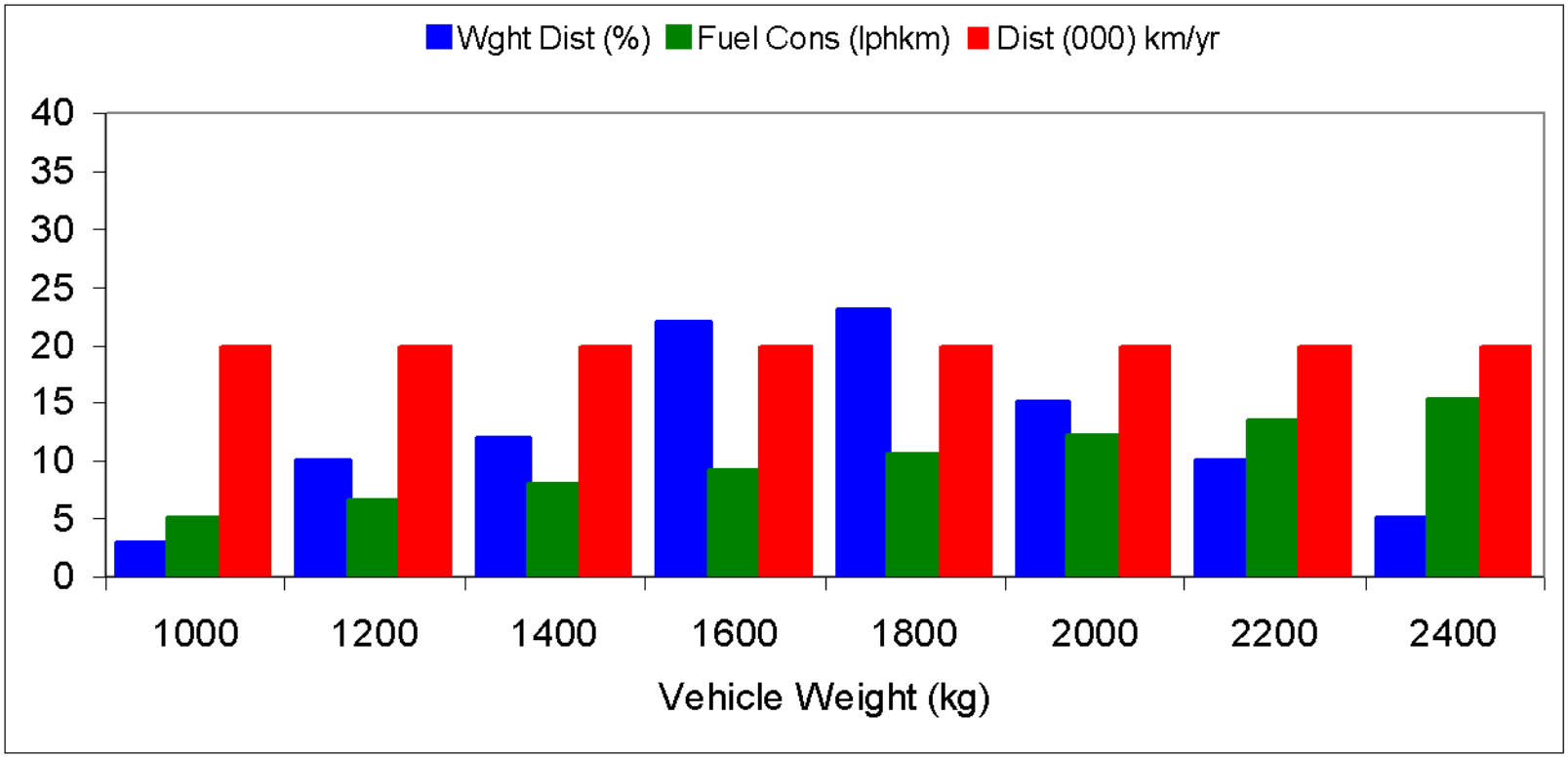
Personal Mobility Options

- Vehicle Size Distribution – time for urban commuter vehicles?
  - Safety by Design NOT by Weight
- Engine Displacement
  - Torque by Design NOT by Size
- Technology/Policy Intertwined

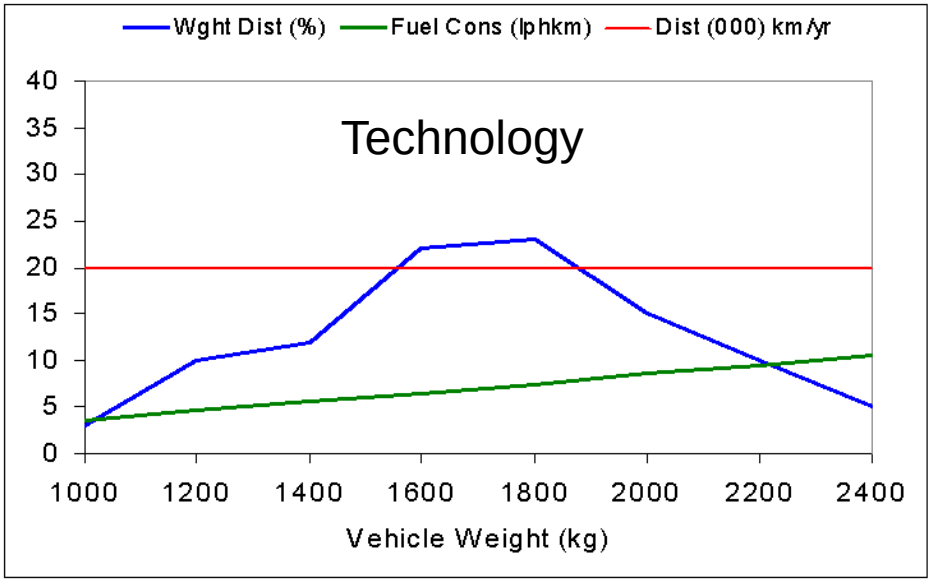
- Public Transport – not discussed, not because it is not important but because it is way beyond my knowledge base
- Bicycles – Dave Foster

Baseline



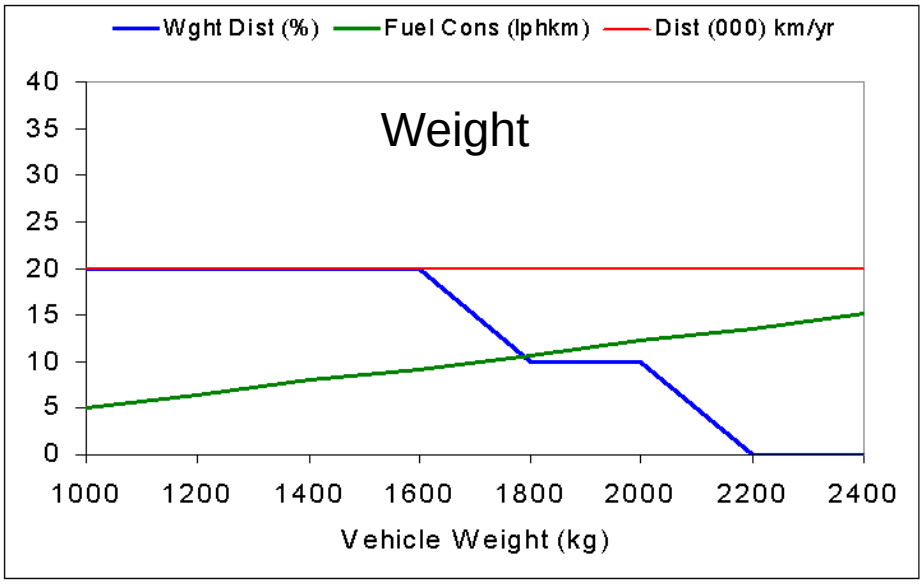
- Total vehicle population – 240 million
- Size distribution slightly “doctored” up – bracketing, approximation etc
- Distance traveled assumed same for all vehicle sizes – 20,000 km/yr consisting of commute at 14,000 km/yr plus “other” at 6,000 km/yr – DoT data
- Fuel consumption data from NSF report on CAFE impact
- Calculated results consistent with DoE data
  - Total fuel consumed **128** billion gall/yr
  - Total distance traveled **4800** billion vehicle-km/yr

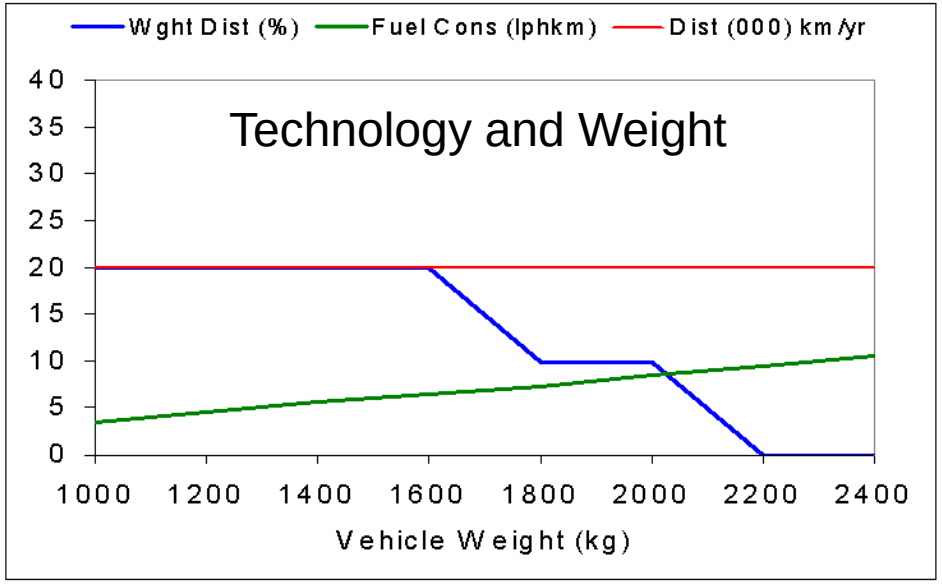
Conventional Use Pattern
Impact of Technology & Weight Distribution



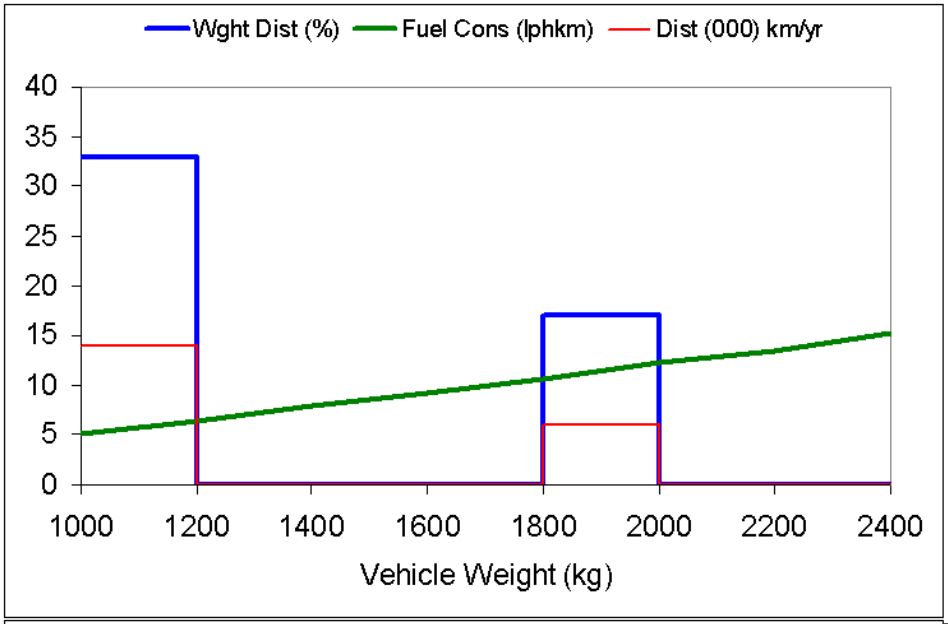
- 20,000 km/yr for all vehicles
- 4,800 Bkm/yr total vehicle-distance

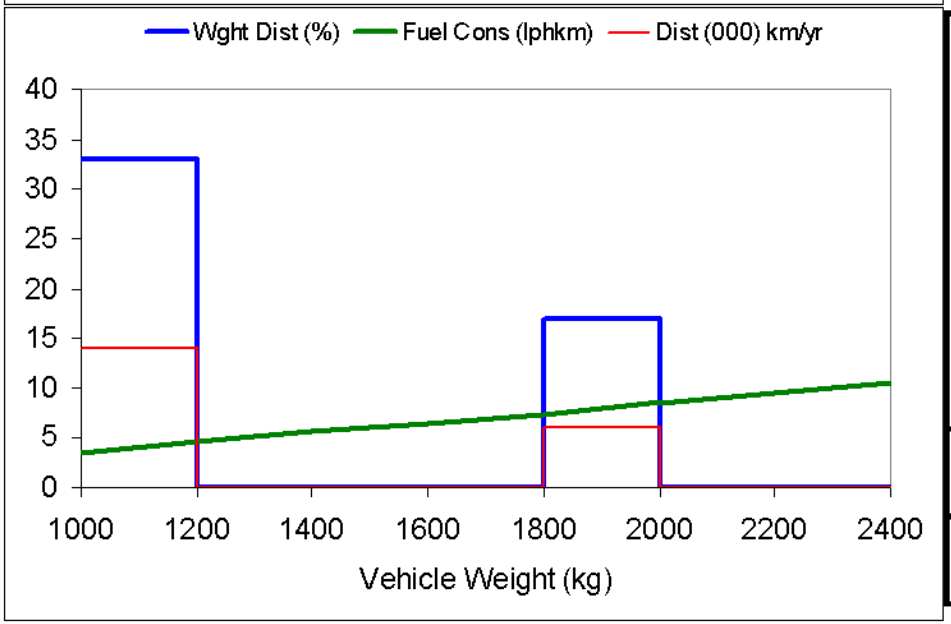
		Baseline	Wght Dist	Technology	WtDst+Tech
Fuel	Bgall/yr	128	101	90	71
Diff	%		21	30	45





Bi-Modal Weight Distribution
The Right Vehicle for the Right Use





- Number of vehicles increased to 430 mill vs baseline of 240 mill
- Commute and “other” distance traveled same as baseline
- Total vehicle distance maintained at 4800 B vehicle-km/yr
- Weight reduction through innovative materials application additive to these savings
- SAFETY ?????

		Baseline	Bi-Modal	Bi-Mdl+Tech
Fuel	Bgall/yr	128	86	60
Diff	%		33	53

Redefine Safety

Our analysis differs from the IIHS analysis in important ways, however. First, we focus on the risk not only to occupants of vehicles of type A, but to occupants of other vehicles that crash with type-A vehicles. In our individual decisions as buyers of vehicles, as well as citizens in decisions about public policy, we need information on how dangerous vehicles are, to both their occupants and others. A shortcoming of many safety analyses has been that only risks to drivers or

AN ANALYSIS OF TRAFFIC DEATHS BY VEHICLE TYPE AND MODEL

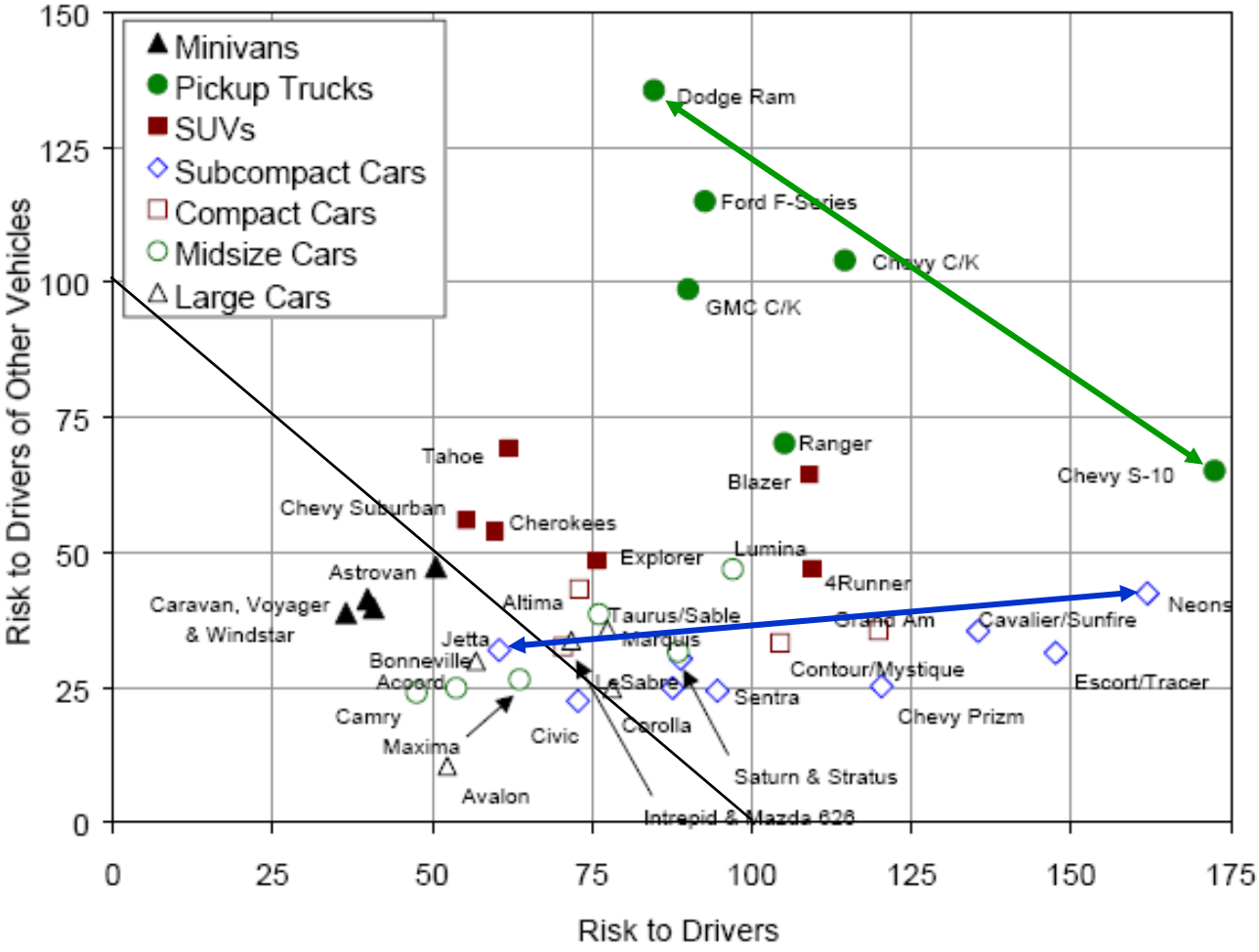
Marc Ross, University of Michigan, Physics Depart
Tom Wenzel, Lawrence Berkeley National Labora

March 2002

Report Number T021

- Observe the range for vehicles of the same class/weight
- Safety by design NOT by weight

… with these data go where the authors feared to tread ...

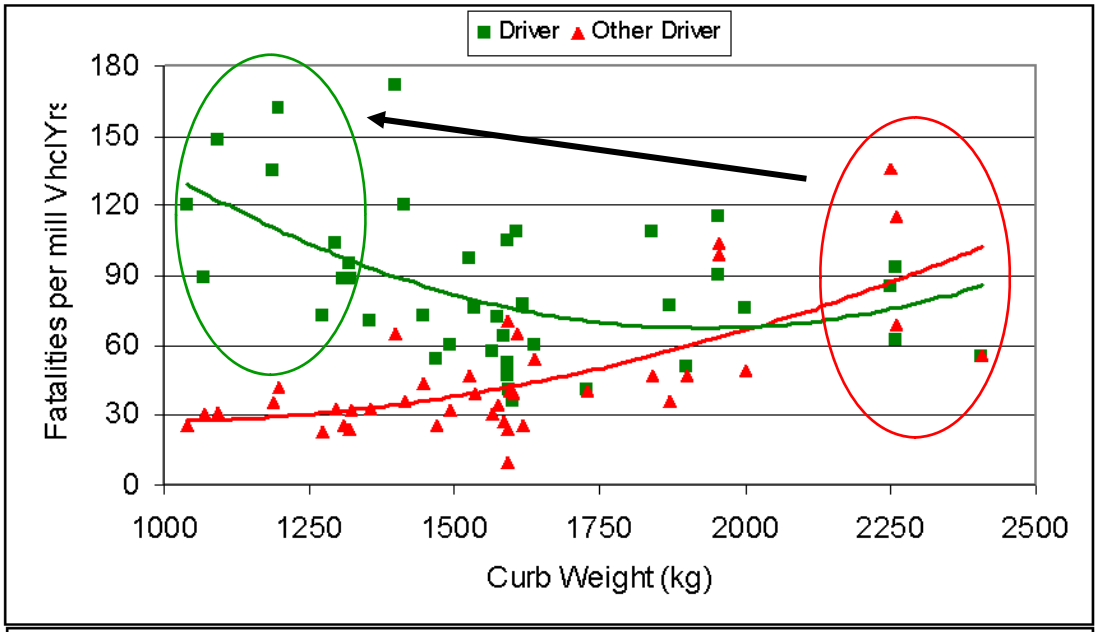


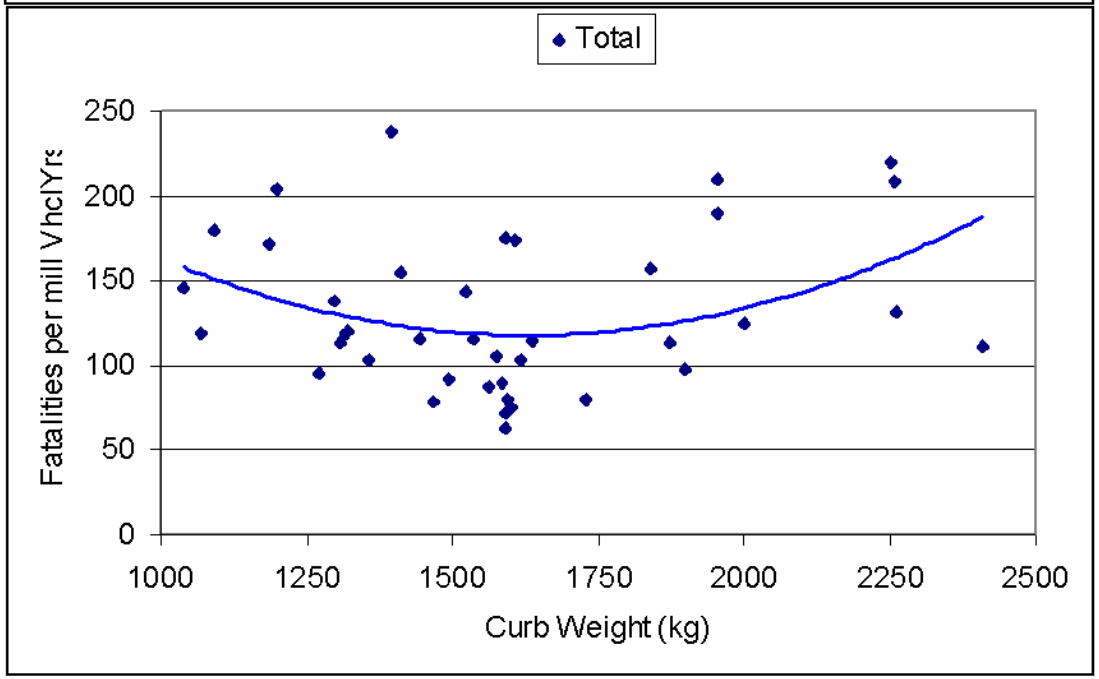
Lighter is Safer!

- There is no causality to these graphs
- There is no logic to the quadratic curve fit chosen to show data trends
- Ross and Wenzel explicitly chose not to plot data this way

… but I want to make a point …

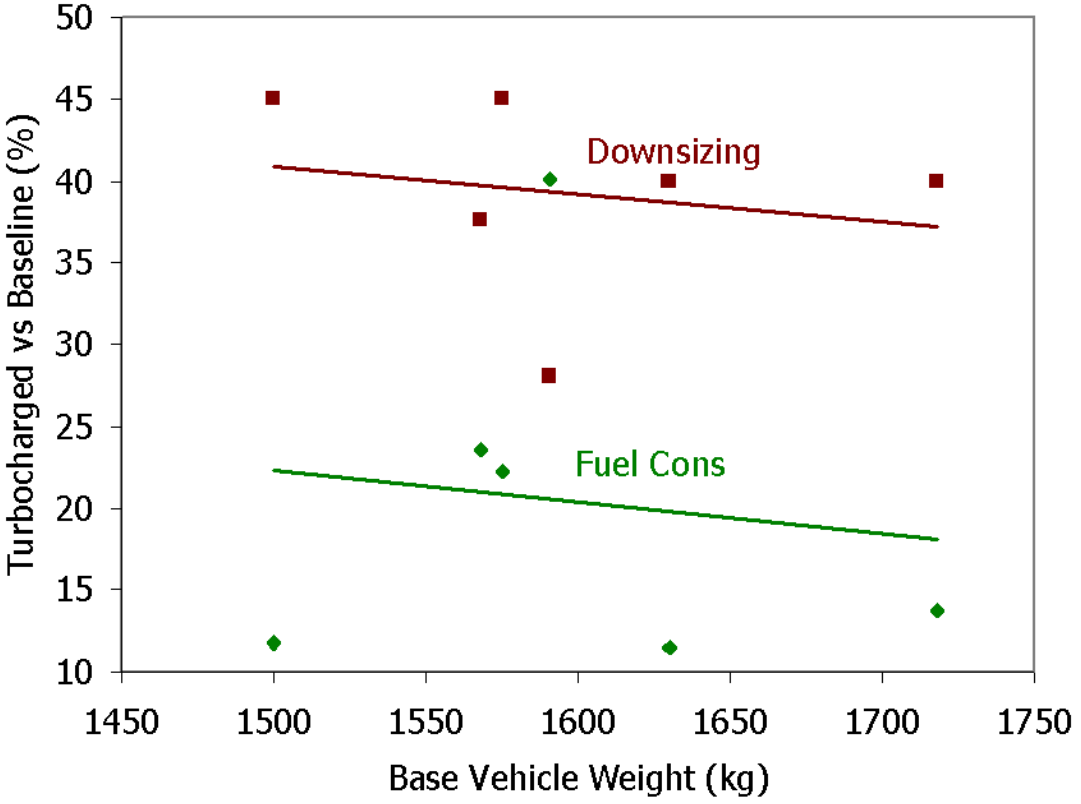
- Examine the relationship between fatalities in light cars as result of the effect of heavy vehicles
- Ask - “if heavy vehicles are reduced, does total fatality reduce”.
- The problem of “transition”- why was the question not raised during upsizing?





Torque by Design NOT by Displacement

- High torque requirement at low speeds dictates engine rating/displacement
- High displacement engine has to be throttled more at part loads. Throttling by far the major loss mechanism.
- Downsizing is an effective way to improve fuel economy while restoring torque by “other” means
- 2009 Model Year vehicles for sale in the US
- Same model and make naturally aspirated and downsized turbocharged engine options
- Average downsizing ~40%
- Average fuel consumption reduction ~20%
- Low speed torque, turbo response and engine knock – major issues

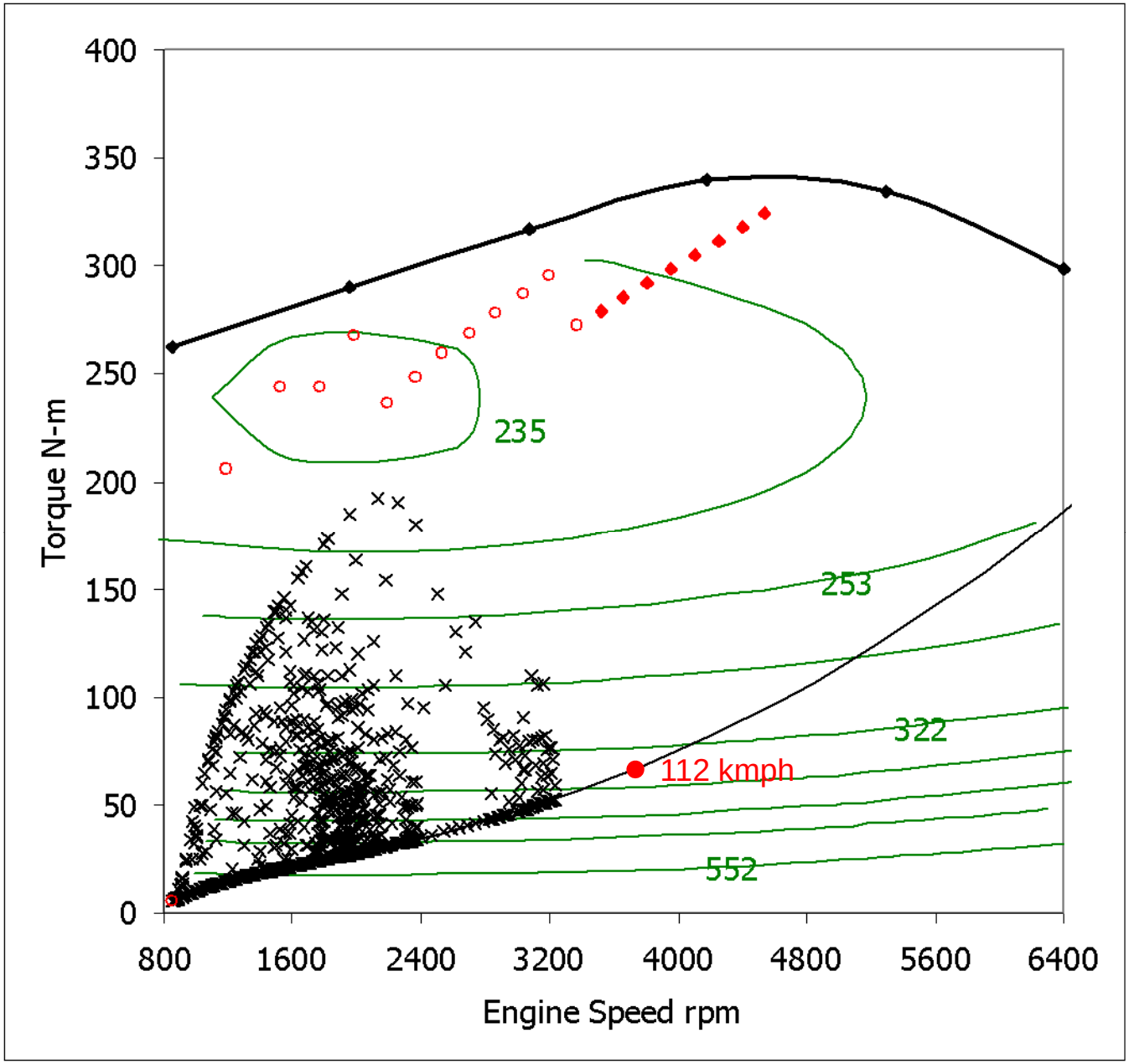


Calculation Procedure

- Simple spreadsheet based calculation of rolling resistance, aerodynamic drag and inertia (neglecting rotational inertia) to calculate vehicle power requirement second by second over the FTP cycle for a 1650 kg vehicle with a 200 kW engine
- Curve fit of transmission characteristics used to calculate engine speed and torque
- Curve fit of engine BSFC as a function of speed and torque used to calculate fuel consumed at each point – summation over the cycle
- Steady state torque required as a function of speed
- 0-96 kmph in 12 seconds – “not behind me”
- 96-145 kmph in 8 seconds – highway passing

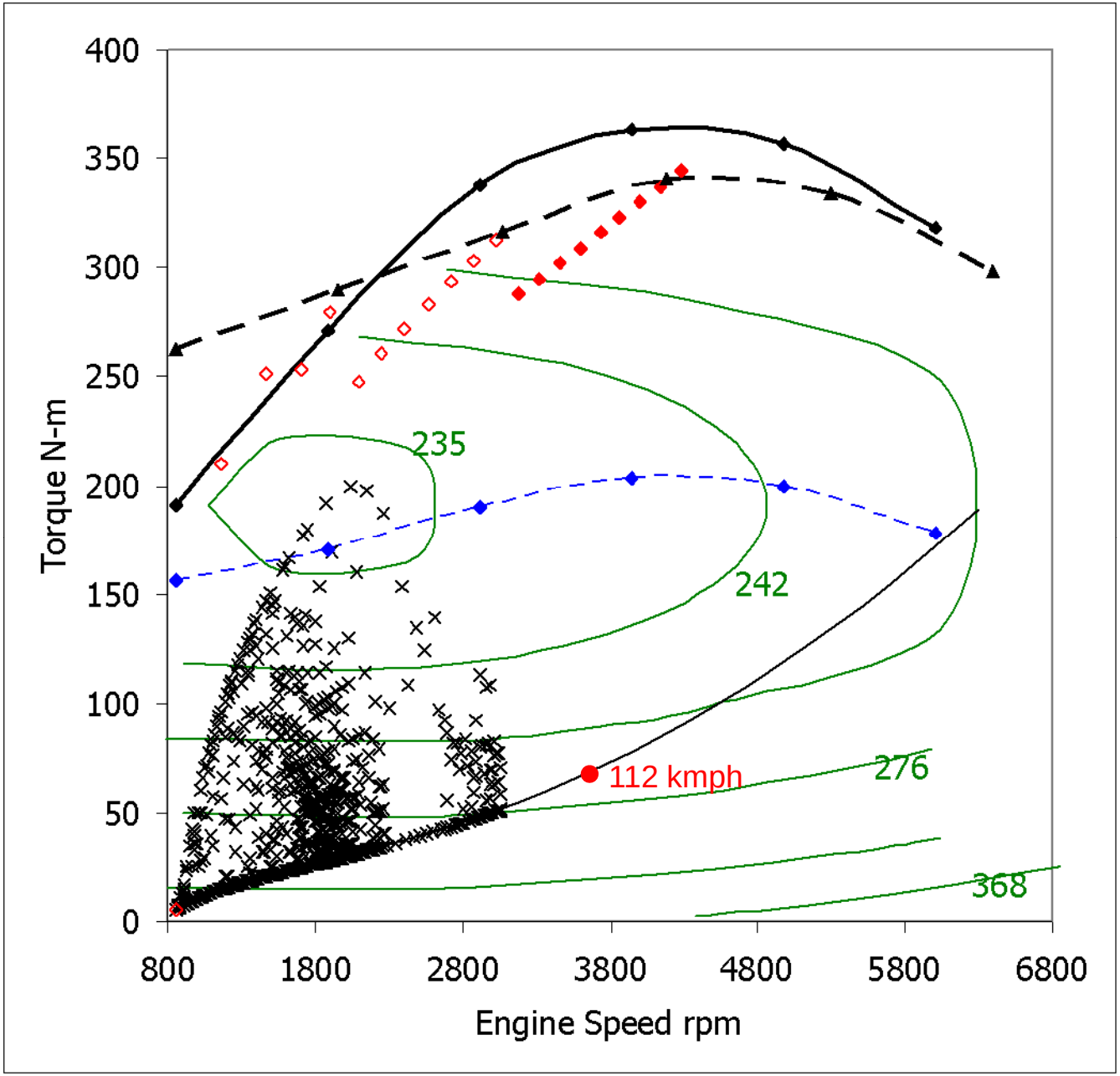
Naturally Aspirated Large Displacement Engine

- Engine sized for low speed torque
- Considerable throttling under urban driving and steady state conditions
- High BSFC values at low torque
- Most operating points in high BSFC region far away from the optimum



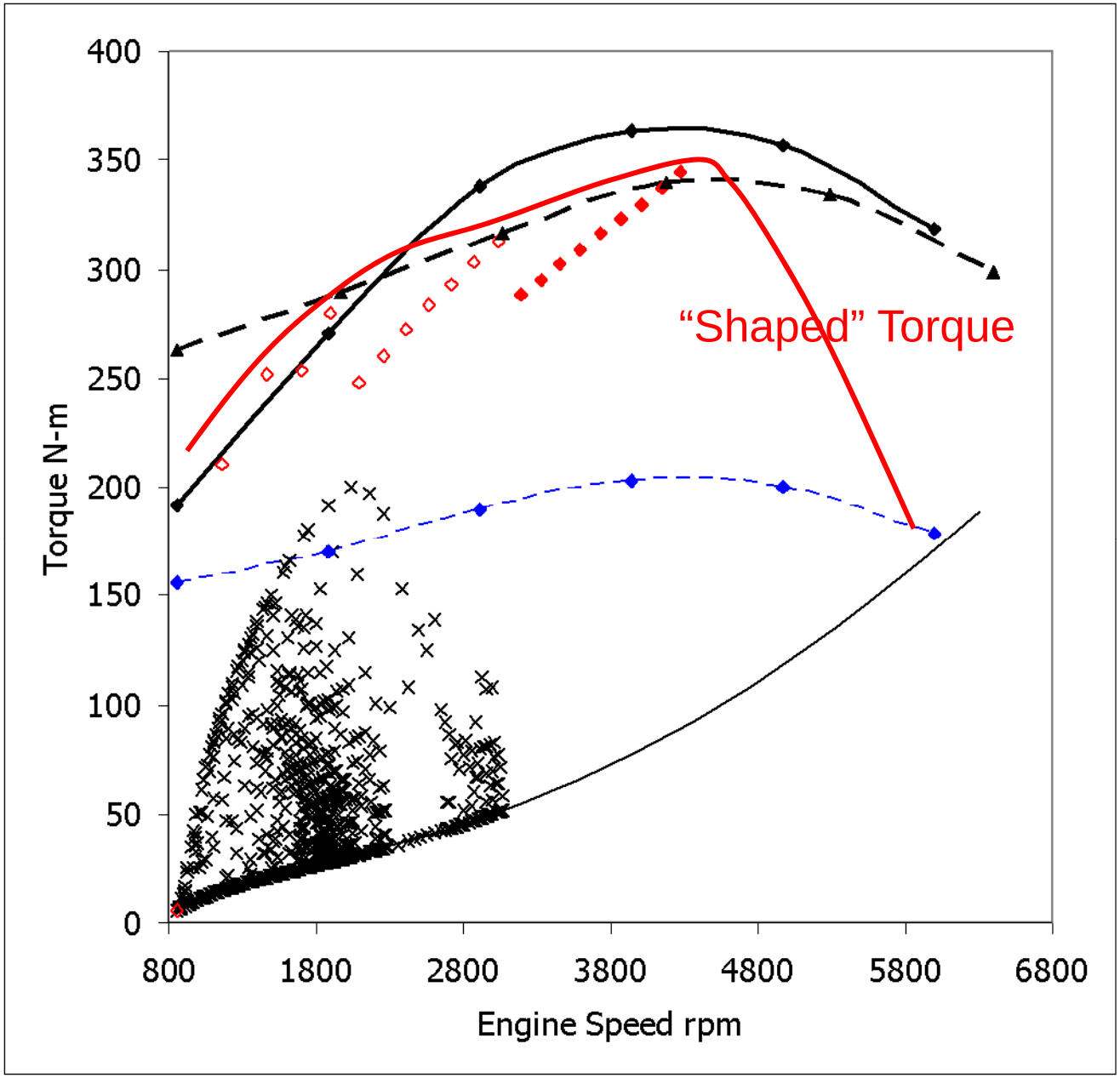
Turbocharged 40% Downsized Engine

- Engine torque restored by turbocharging
- Torque deficit at low engine speeds – compressor limit
- Less throttling at low torques
- Compare BSFC values at low torque with large displacement engine
- Most operating points in better BSFC region
- Torque line for compressor PR=1
- Turbo in use infrequently



Torque Shaping – Technology Choices

- Torque “shaped” per driving requirements
- Torque deficit of turbocharged downsized engine at low speeds; turbo lag effects are additional
- Torque deficit of naturally aspirated downsized engine
- Fill the torque deficit with battery, motor/generator
- Tradeoff of additional weight and cost
- Fill the deficit of turbocharged downsized engine with light weight, high power density ultracapacitor



The Torque Deficit - Issues

- Fill torque deficit with battery and motor/generator
  - Spreadsheet based calculation shows that brake energy recovery is used up in energy consumption of added weight
  - Net benefit attributable to engine downsizing (less throttling) and shut off during vehicle stops, coasting and braking
- Fill torque deficit with turbocharging
  - Compressor range issue can be addressed with two stage turbocharging or with SST - SAE 2009-01-1472
  - SST and 2-Stage also address turbo-lag issues
- Combination of the two (downsizing, turbocharging plus light weight energy storage) appears to provide a more optimum solution
- Further downsizing of engine continues to show fuel economy benefits. Engine knock – the perennial combustion problem – comes back begging for a solution

Technology/Policy Issues Solutions & Prospects

- Technology is political – prospects - squarely face how we got here; the result of the “frozen chicken tax”; and now the safety myth – parallels with the security myth
- The advent of the commuter car – the right vehicle for the right use
- Safety by design NOT by size; lighter is safer
- Smaller displacement engines – the right engine for the right use – the cost of catering to $C_{19}H_{28}O_2$
- Torque by design NOT by displacement
- Optimization of the overall powertrain – energy density, power density of both the storage system and the powerplant
- Optimization of urban planning, public transport, even bicycle paths for Dave Foster