Tire Pressures and Sustainability:
The Economic and Environmental Effects of Under-Inflated and Over-Inflated Tires at Williams College

Sam Baldwin
GEOS 206
Professor Dethier
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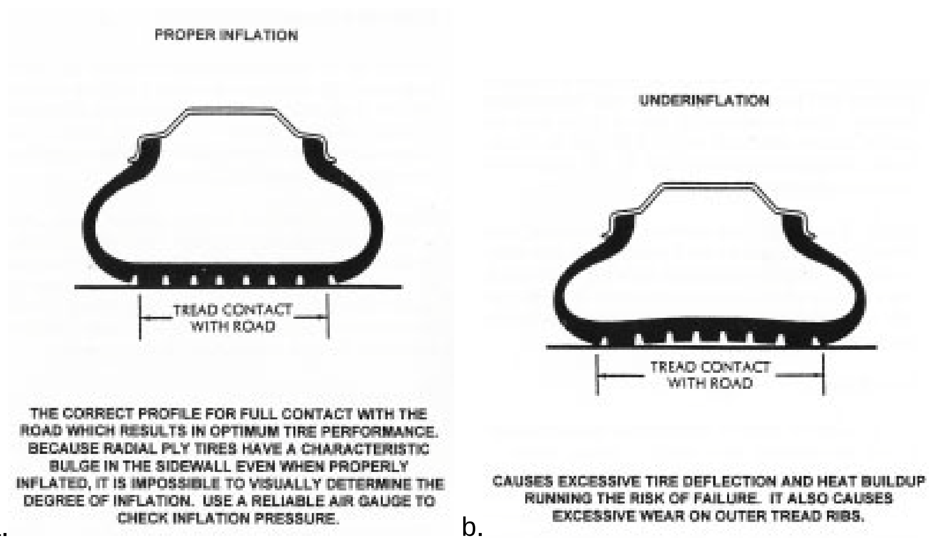
Introduction:

Global awareness concerning the effects of tire pressure on fuel efficiency and tread wear accompanies periods of increased fuel costs as well as environmental movements towards more sustainable automobile practices. As gas prices were rising in 2006, for example, tire manufacturer associations were promoting more sustainable tire maintenance procedures to facilitate cost cutting for car owners (Jones, 2006). Similarly, environmentally conscious individuals tend to monitor the tire pressures of their vehicles more often in order to reduce their carbon dioxide emissions. Although the environmental and economic effects of maintaining recommended tire pressures in all of the vehicles owned by Williams College are minor relative to the effects of other behavioral or material changes that the college might consider, the establishment of a campus-wide policy to require tire pressure maintenance sets a precedent among colleges and universities and encourages conscientiousness among college affiliates regarding their personal environmental footprints.

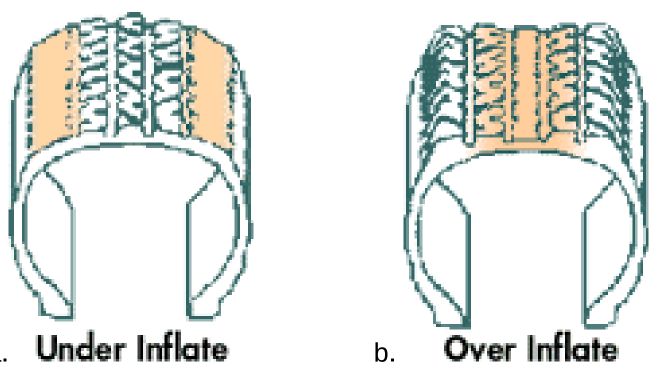
The best available data suggest that Williams College owns 77 vehicles, which implies that the college is responsible for 308 tires on the road at any given time. The impact of 308 tires seems minimal; however, both under-inflated and over-inflated tires contribute to higher vehicle maintenance costs (economic and environmental) in addition to increased CO_2 emissions. Under-inflated tires become flatter along the surface in contact with the road, increasing their internal heat and rolling resistance. Consequently, under-inflated tires suffer from excessive and accelerated tread wear particularly along their edges (see Figures 1 and 2a), which reduces their life expectancies by as much as 25%, (Air, 2010) and they suffer from a reduction in fuel efficiency by as much as 3.3%

(Keeping, 2001). Tire over-inflation causes uneven tread wear particularly along the center of the tire (see Figure 2b) and increases the possibility of explosive decompression (Tire, 2010).



a. b.

Figure 1: a. Illustrates the profile of a properly inflated tire, showing the correct amount of tread contact with the road. b. Depicts the profile of an under-inflated tire, demonstrating how under-inflation increases tread contact with the road as well as how under-inflation generates disproportionate tread wear. (http://www.nitrogentiremachine.com/proper_tire_inflation.htm).



a. b.

Figure 2: a. Exemplifies the increased tread wear along the edges of an under-inflated tire. b. Illustrates the increased tread wear along the center of an over-inflated tire. (http://www.nitrogentiremachine.com/proper_tire_inflation.htm).

This project studies the impact of Williams College vehicles' tire pressures on CO_2 emissions, fuel costs, and sustainability issues while addressing the feasibility of instituting a policy requiring improved tire maintenance practices.

Method:

Using the spreadsheet outlining the years, makes, models, identification information, and departments of Williams College vehicles provided by Tim Reisler (Assistant Director for Administrative Services at Facilities) as a guide for locating the vehicles on campus, I tested the tire pressures of all 4 tires on 66 out of 77 Williams College vehicles with a dial tire pressure gauge. (Note: I was unable to locate the remaining 11 vehicles.) Afterward, I calculated the overall difference between the recommended tire pressures for each vehicle and actual, observed tire pressures for each vehicle. From the driver's side doorjamb, I recorded the recommended tire pressures for all of the unlocked vehicles; for the locked vehicles, I estimated the recommended tire pressures based on similar makes and models. Typically utilizing used car sales websites, I located and recorded the U.S. Environmental Protection Agency (EPA) estimated fuel economies for each vehicle.

Based on the U.S. Department of Energy statistic that under-inflated tires reduce gas mileage by 0.3% for every 1 pound per square inch (psi) decrease in pressure of all 4 tires (Keeping, 2001), I calculated the percentage change in fuel economy and found the adjusted fuel economy for each under-inflated vehicle (in miles per gallon). Then, using 2007 data from Katie White's project and assuming that each department currently drives the same number of miles per year despite potential changes in fleet size, I calculated the number of miles driven within each department and divided that figure by the number of vehicles in the department. Using the resulting mileage figures with the EPA estimated and adjusted fuel economy figures as computed above, I finally calculated the number of gallons of gas used by each vehicle under recommended tire pressure conditions as well as adjusted tire pressure conditions and, assuming that gas costs $2.75 per gallon, calculated the amount of money spent on gas each year under both conditions. In order to ascertain how many pounds of CO_2 are emitted under each of the conditions, I used the statistic from the EPA maintaining that 19.4 pounds of CO_2 are emitted for every gallon of gas consumed (Emission, 2005). Furthermore, with regard to tread wear, I used the statistic that for every 10% decrease in tire inflation, tire life decreases by 10% (Tire Inflation).

For over-inflated tires, I quantitatively examined the data in spreadsheet form, qualitatively analyzed the effect of over-inflation on tire life expectancy, and researched the resulting negative impacts on sustainability.

Data:

The tire pressure measurements reveal that only 1 out of 66 Williams College vehicles tested had the proper tire pressure overall; however, even that vehicle demonstrated inconsistencies in recommended and actual pressures within each tire. Moreover, 23 vehicles had under-inflated tires overall (see Appendex A), and 37 vehicles had over-inflated tires overall (see Appendex B). (Note: 5 of the vehicles tested were too problematic to include and analyze: 1 vehicle had a flat tire, and 4 vehicles had inaccessible valves.)

Under-Inflation Data and Analysis:

Vehicles with under-inflated tires overall experienced a range of percentage loss in fuel economy from 8.325% to 0.225% (see Appendix A and Figure 3). The differences appear to be negligible when viewing each vehicle independently; however, when considering the total miles per gallon lost for all under-inflated vehicles, the difference seems more significant (see Figure 4).

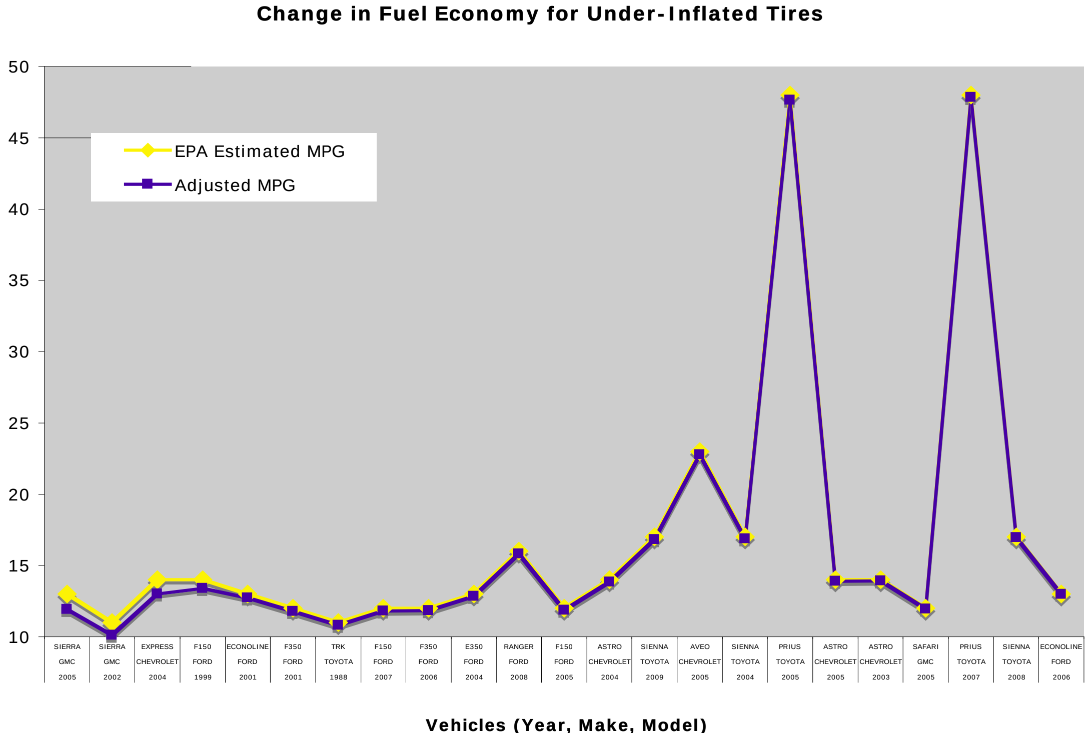


Figure 3: Graph depicts fuel economy (in mpg) for each vehicle under EPA estimated conditions and observed, under-inflated conditions. Notice how the difference appears to be slight for each vehicle.

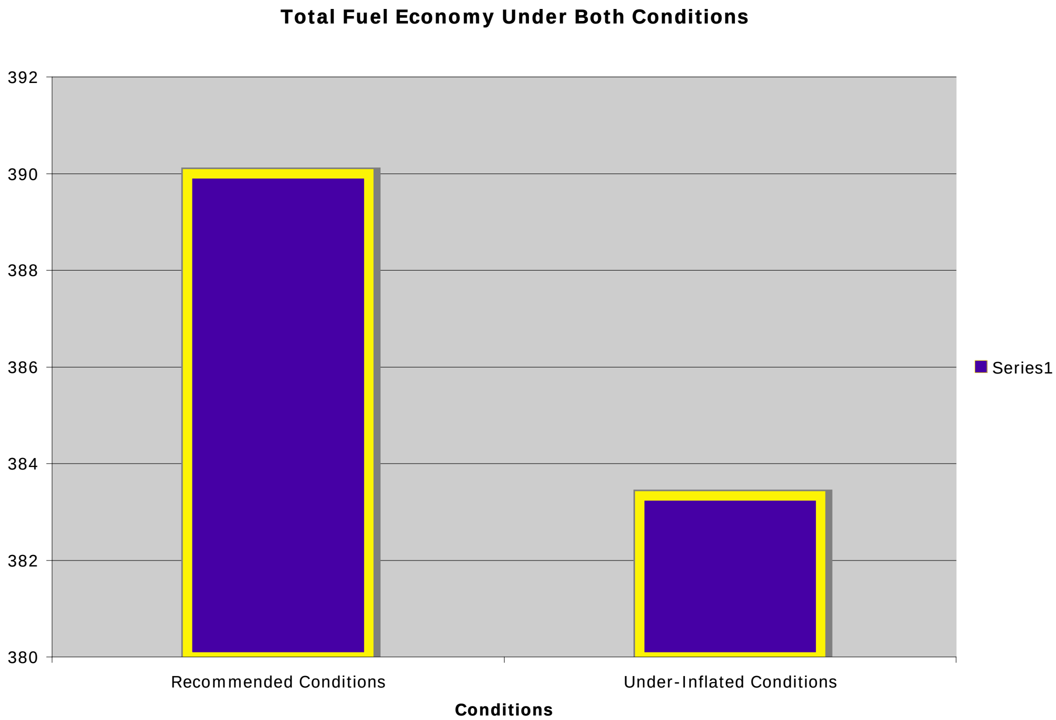


Figure 4: Graph illustrates total fuel economy among all under-inflated vehicles for recommended conditions and under-inflated conditions. Notice how the difference appears to be more considerable when comparing total values.

I calculated that vehicles with under-inflated tires overall use 182.58 extra gallons of gas each year (see Appendices C and D), which, at $2.75 per gallon, costs Williams College approximately $502.10 extra each year (see Appendices E and F). Again, considering each vehicle by itself diminishes the overall differences; that is, the differences in the number of gallons of gas and the amount in dollars spent on gas each year appear to be minor when examining individual vehicles but look more significant when considering their annual totals. Furthermore, assuming that 19.4 pounds of CO_2 are emitted for every gallon of gas consumed (Emission, 2005), I calculated that Williams College emits 3,542.05 extra pounds of CO_2 each year due to under-inflated tires (see Appendix G).

With regard to the excess tread wear resulting from under-inflated tires and using the statistic that tire life expectancy decreases by 10% for every 10% of under-inflation (Emission, 2005), I conclude that Williams College tires (in the most extreme cases of under-inflation) are losing up to 8% of their life expectancies. Assuming that tires last nearly 80,000 miles now (Tire Aging, 2010), this percentage loss indicates that under-inflated tires are being disposed of up to 6,400 miles sooner than they would be under recommended tire pressure conditions.

In terms of under-inflation as a departmental problem, the tires on the 3 vehicles used by OIT are all considerably under-inflated. I reason that this observation is a reflection of a departmental issue pertaining to vehicle maintenance. Similarly, 16 of the 36 vehicles used by Facilities that I tested suffer from under-inflation; however, my policy recommendations do not require further inquiry into the sources of these departmental observations.

Over-Inflation Data and Analysis:

Out of the 66 vehicles tested at Williams College, 37 had over-inflated tires overall. The degree of over-inflation for each of these vehicles ranged from 1 pound per square inch to 96 pounds per square inch, and the total amount of over-inflation was 1,096 pounds per square inch among the 37 over-inflated vehicles combined (see Appendix H).

Vehicles with over-inflated tires are not analyzed quantitatively because of a lack of available data and resources; however, their negative environmental impacts are evident. First, the life expectancies of over-inflated tires are reduced as a result of excess tread wear. Extrapolating from the 10% decrease in life expectancy for every 10% reduction in inflation, I speculate that over-inflated tires suffer even more extreme tread wear because the surface area of the center of the tread, which contacts the road more exclusively for over-inflated tires, is most likely smaller. That is, since the tire contacts the road only along the center of the tread when it is over-inflated, and the center of the tread has less surface area than the entire tread, over-inflated tires must suffer from increased contact in a more concentrated area and thus more severe tread wear than under-inflated tires or tires with recommended pressures. Hence, I conjecture that the life expectancy of over-inflated tires most likely decreases by more than 10% for every 10% increase in inflation. Again, assuming that tires last nearly 80,000 miles (Tire Aging, 2010), a 15% reduction in life expectancy would result in a loss of 12,000 miles per tire; a 20% reduction in life expectancy would result in a loss of 16,000 miles per tire; and so on. With drivers forcing tires into retirement earlier than necessary, more and more tires are piling up in landfills and contributing to the problem of unsustainable tire disposal methods.

According to *Discover* magazine, in the United States alone, 300 million tires are discarded every year. An average castoff tire weighs 22.5 pounds and produces approximately 2 gallons of fuel in addition to other combustible carbon compounds when burned. These used tires are extremely flammable and have been responsible for massive fires, including the 1998 devastating fire in San Joaquin Valley during which 7 million tires burned for two and a half years (Gugliotta, 2008). Approximately 55,000 gallons of runoff oil are unleashed into the environment for every 1 million tires ignited (Tire Fires, 2010); hence, approximately 385,000 gallons of runoff oil were released in the San Joaquin Valley fire. Moreover, tire fires pollute the air with emissions including polycyclic aromatic hydrocarbons, benzene, styrene, phenols, and butadiene (Tire Fires, 2010). Large tire dumping wastelands also contribute to the spread of infectious diseases as they are inhabited by vermin and conveniently cater to mosquitoes as desirable breeding grounds (Gigliotta, 2008).

Discussion and Recommendations:

Although the environmental and economic effects of under-inflated tires at Williams College are noticeable, they are less severe than similar effects generated by numerous other sources. Addressing tire pressure through policy at Williams, though, would set a precedent among other colleges and universities, and it would help spread awareness to individuals about the negative externalities and monetary losses associated with improperly inflated tires. Rather than trying to solely enforce a top-down style policy that might make vehicle users or particular departments feel targeted (i.e. OIT), I would recommend that the college arrange a “tire pressure awareness celebration” day in which the college gives out tire pressure gauges and information about the negative externalities and safety hazards associated with improper tire pressures. On that day, Williams could institute its policy to require vehicle users to check tire pressures when filling up their vehicles with fuel. By making this transition about awareness rather than strict enforcement, vehicle users are less likely to feel overwhelmed and more likely to share the statistics relating to the importance of maintaining proper tire pressures with their families and friends.

Moreover, I recommend that a future student in GEOS 206 examine tire disposal at Williams and relate it to both worldwide tire recycling progress and problems. The percentage of used tires being recycled in the United States has risen from virtually 0% in 1990 to 30% in 2005 (Gugliotta), marking a promising movement toward more sustainable means of tire disposal. In 1992, processors began grinding up used tires and converting them into sidewalks, playground surfaces, and basketball courts. Now, ground-up, used tires are backfilling and insulating new roads, which enhances the roads' "springiness" and makes them longer lasting (Gugliotta, 2008). A follow-up project by a future student could investigate local contributions to these innovative disposal techniques.

For now, Williams College should focus on spreading awareness about the cheap and easy ways to reduce CO_2 emissions and save money at the gas pumps while setting an example through its own actions. Maintaining recommended tire pressures in college and other vehicles is essentially a behavioral issue; checking tire pressures at the gas station should hardly be an inconvenience for any driver. The payoffs for each driver are minor, but, as this study shows, they tend to add up over a number of vehicles.

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Appendices:

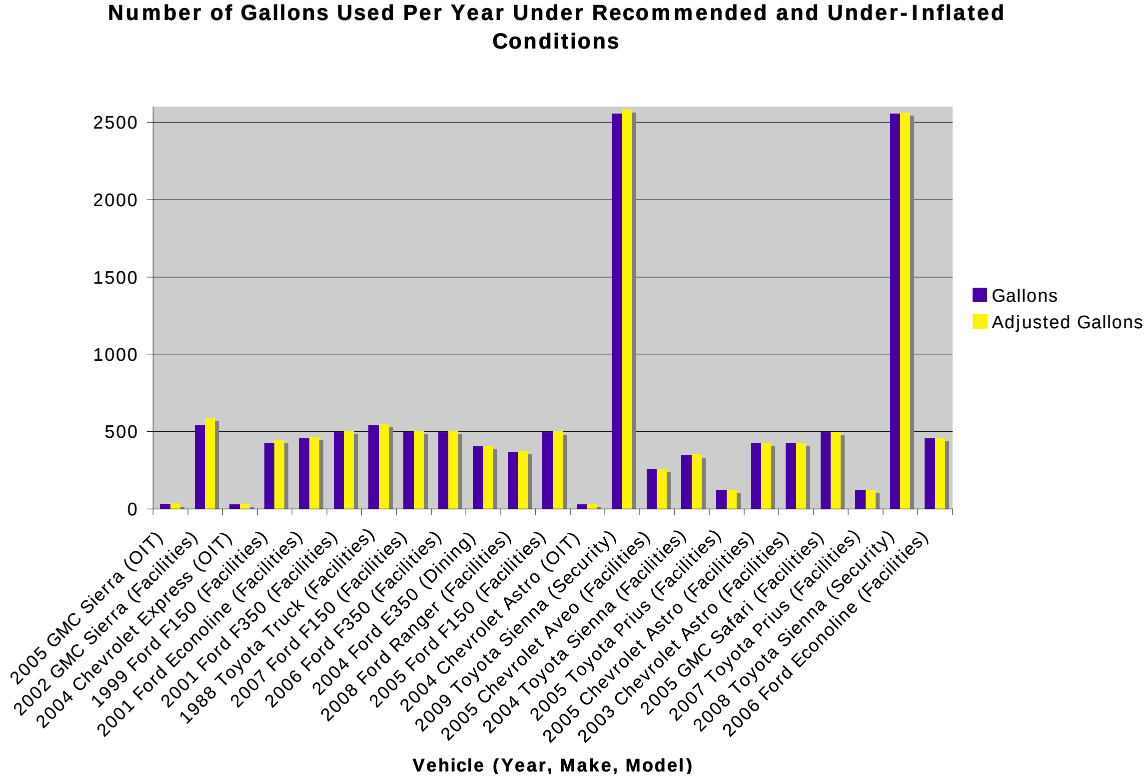
Appendix A: Data Table: Vehicles with (overall) under-inflated tires sorted by percentage decrease in fuel economy. Note: DS-F, DS-R, PS-F, and PS-R refer to driver's side and passenger's side front and rear tires.

Year	Make	Model	Recommended PSI (Front, Rear) in lbs	EPA Estimated MPG	DS-F (lbs)	DS-R (lbs)	PS-F (lbs)	PS-R (lbs)	Overall Difference (lbs)	Percentage Decrease	Adjusted MPG
2005	GMC	SIERRA	65, 65	13	37	38	37	37	-111	8.325	11.92
2002	GMC	SIERRA	65, 65	11	41	32	40	40	-107	8.025	10.12
2004	CHEVROLET	EXPRESS	55, 55	14	34	33	34	35	-95	7.125	13
1999	FORD	F150	45, 45	14	30	37	33	21	-59	4.425	13.38
2001	FORD	ECONOLINE	55, 55	13	56	55	55	25	-29	2.175	12.72
2001	FORD	F350	55, 55	12	46	51	47	51	-25	1.875	11.775
1988	TOYOTA	TRK	35, 35	11	28	30	27	31	-24	1.8	10.802
2007	FORD	F150	45, 45	12	43	45	28	43	-21	1.575	11.81
2006	FORD	F350	55, 55	12	50	52	50	50	-18	1.35	11.838
2004	FORD	E350	55, 55	13	55	54	42	53	-16	1.2	12.84
2008	FORD	RANGER	40, 40	16	37	37	36	35	-15	1.125	15.82
2005	FORD	F150	45, 45	12	39	44	40	43	-14	1.05	11.87
2004	CHEVROLET	ASTRO	38, 38	14	31	36	35	36	-14	1.05	13.85
2009	TOYOTA	SIENNA	35, 35	17	32	32	32	30	-14	1.05	16.82
2005	CHEVROLET	AVEO	30, 30	23	28	25	28	26	-13	0.975	22.78
2004	TOYOTA	SIENNA	35, 35	17	31	32	34	32	-11	0.825	16.86
2005	TOYOTA	PRIUS	35, 32	48	33	30	29	32	-10	0.75	47.64
2005	CHEVROLET	ASTRO	38, 38	14	38	35	35	34	-10	0.75	13.9
2003	CHEVROLET	ASTRO	38, 38	14	34	35	39	35	-9	0.675	13.91
2005	GMC	SAFARI	36, 36	12	34	34	34	35	-7	0.525	11.94
2007	TOYOTA	PRIUS	35, 32	48	32	32	33	32	-5	0.375	47.82
2008	TOYOTA	SIENNA	35, 35	17	32	37	32	35	-4	0.3	16.95
2006	FORD	ECONOLINE	55, 55	13	49	60	48	60	-3	0.225	12.97

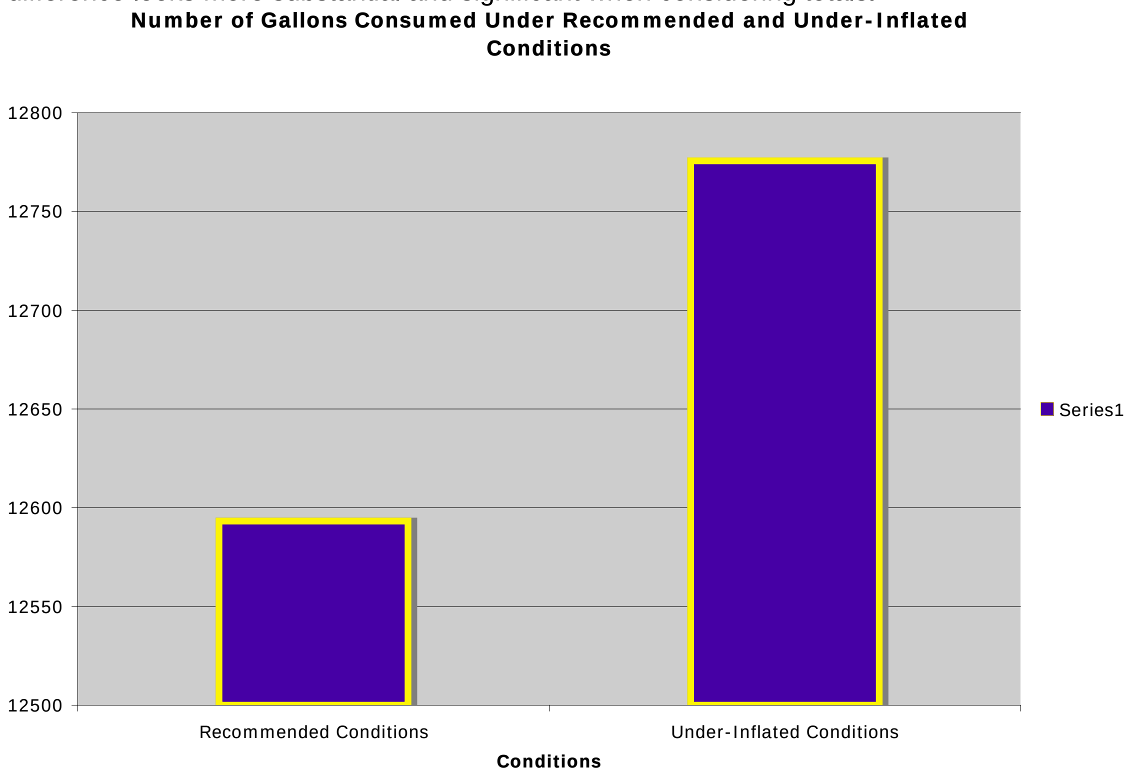
Appendix B: Data Table: Vehicles with (overall) over-inflated tires sorted by overall difference in PSI. Note: DS-F, DS-R, PS-F, and PS-R refer to driver's side and passenger's side front and rear tires.

Year	Make	Model	Recommended PSI (lbs)	EPA Estimated MPG	DS-F	DS-R	PS-F	PS-R	Overall Difference
2000	FORD	F150	45, 45	14	45	45	45	46	1
2006	DODGE	GRAND CARAVAN	35, 35	17	36	36	35	35	2
2003	CHEVROLET	ASTRO	38, 38	14	40	38	40	37	3
2002	CHEVROLET	ASTRO	38, 38	14	38	40	41	39	6
2004	HONDA	CIVIC	35, 32	48	34	32	36	38	6
2006	Dodge	GRAND CARAVAN	35, 35	17	35	39	36	37	7
2007	TOYOTA	HIGHLANDE R/HYBRID	32, 32	27	35	34	32	35	8
2006	FORD	ECONOLINE	55, 55	13	55	57	57	60	9
2004	GMC	SAVANA	55, 55	11	45	65	41	60	9
2008	TOYOTA	PRIUS	35, 33	48	35	37	39	37	12
2002	GMC	SAFARI	36, 36	12	42	39	40	38	15
2005	CHEVROLET	ASTRO	38, 38	14	44	42	40	42	16
2004	CHEVROLET	G1500	38, 38	15	43	43	42	42	18
2005	CHEVROLET	AVEO	30, 30	23	35	35	34	35	19
2004	TOYOTA	SIENNA	35, 35	17	40	40	39	41	20
2006	FORD	E-350	55, 55	14	58	64	57	64	23
2001	DODGE	CARAVAN	35, 35	17	42	41	41	40	24
	CHEVROLET	AVEO	30, 30	23	36	36	37	36	25
2005	TOYOTA	SIENNA LE	35, 35	17	42	45	40	40	27
	GMC	SAFARI	36, 36	12	41	46	43	42	28
2003	FORD	F450	70, 75	12	78	82	78	80	28
2007	GMC	SAVANNA	55, 55	11	62	62	62	62	28
2007	TOYOTA	SIENNA	35, 35	17	38	42	45	46	31
2009	Chevrolet	EXPRESS	55, 55	14	53	72	53	74	32
2008	TOYOTA	SIENNA	35, 35	17	43	44	42	45	34
2005	TOYOTA	CAMRY	32, 32	18	43	39	42	39	35
2006	GMC	SAVANA	55, 55	11	62	63	64	66	35
2009	Chevrolet	EXPRESS	55, 55	14	54	75	56	76	41
2007	Ford	ECONOLINE E250	55, 55	13	66	67	63	67	43
2008	GMC	SAVANA	55, 55	11	55	79	52	78	44
2004	GMC	SAVANA	55, 55	11	59	75	60	75	49
2004	GMC	SAVANA	55, 55	11	62	74	65	68	49
2004	GMC	SAVANA	55, 55	11	60	72	61	77	50
2006	GMC	SAVANA	55, 55	11	75	64	73	62	54
2008	DODGE	SPRINTER	60, 60	26	68	79	70	78	55
2005	FORD	F350	55, 55	12	70	76	71	77	74
2009	FORD	E350	55, 55	14	78	80	80	78	96

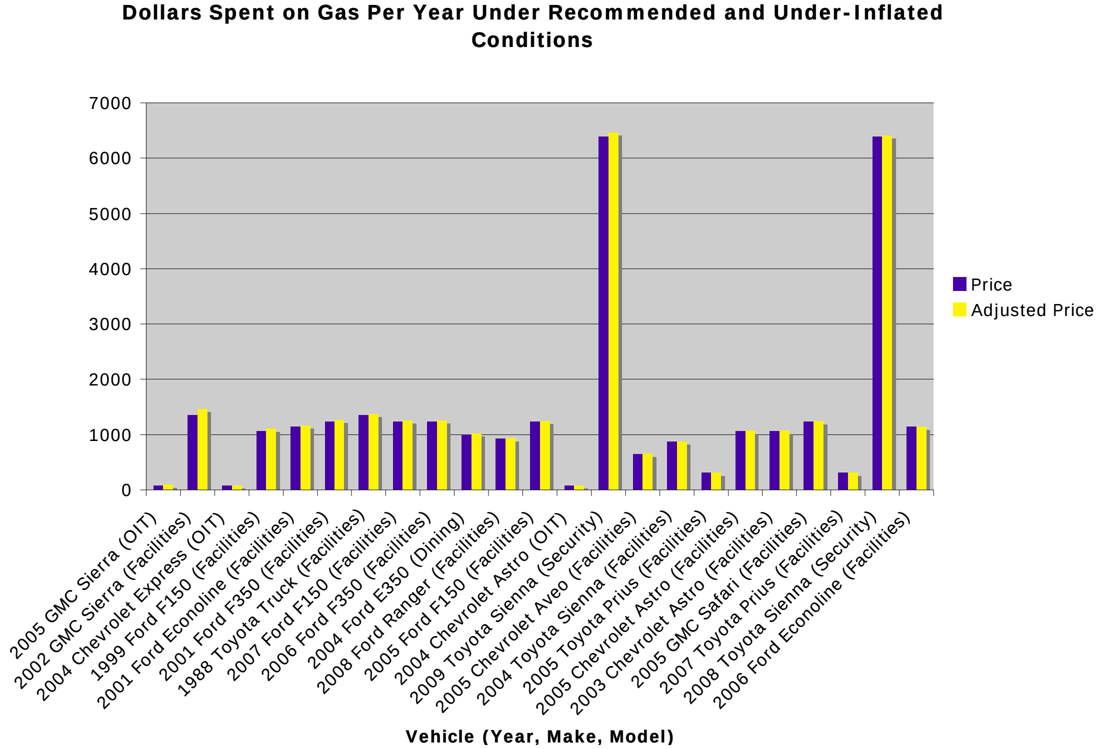
Appendix C: Graph illustrates the number of gallons of gas used by vehicles with observed under-inflation under recommended and under-inflated conditions each year. Notice how the difference appears to be negligible for each vehicle.



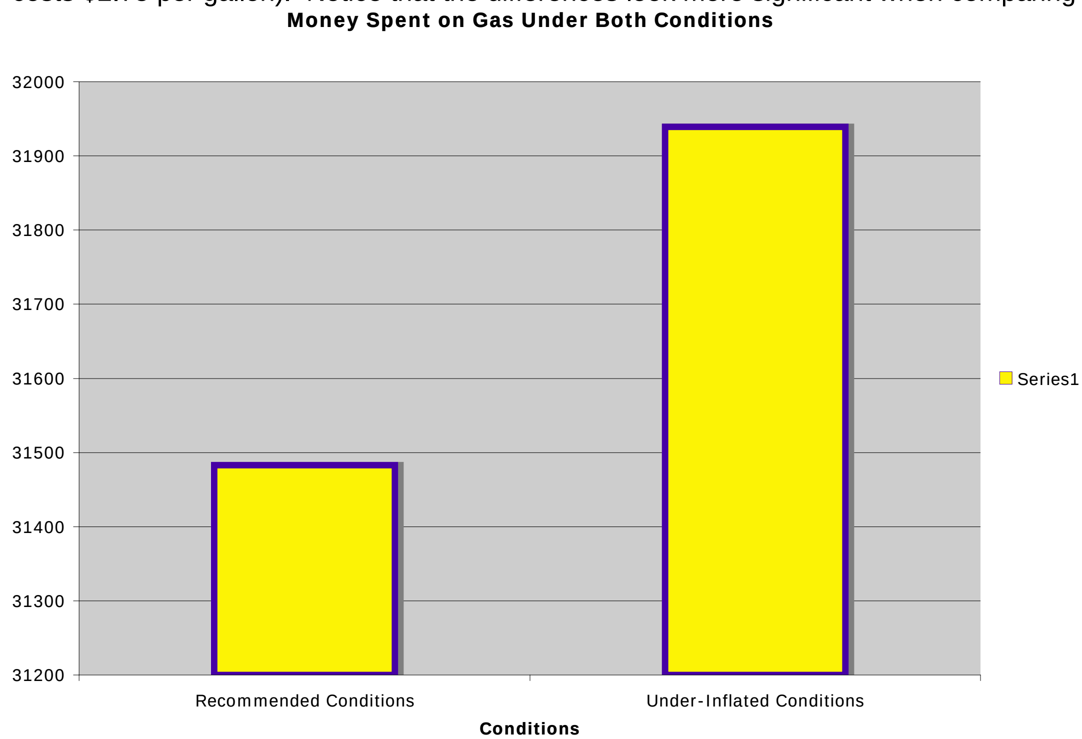
Appendix D: Graph shows the total number of gallons of gas consumed by vehicles with observed under-inflation under recommended and under-inflated conditions each year. Notice how the difference looks more substantial and significant when considering totals.



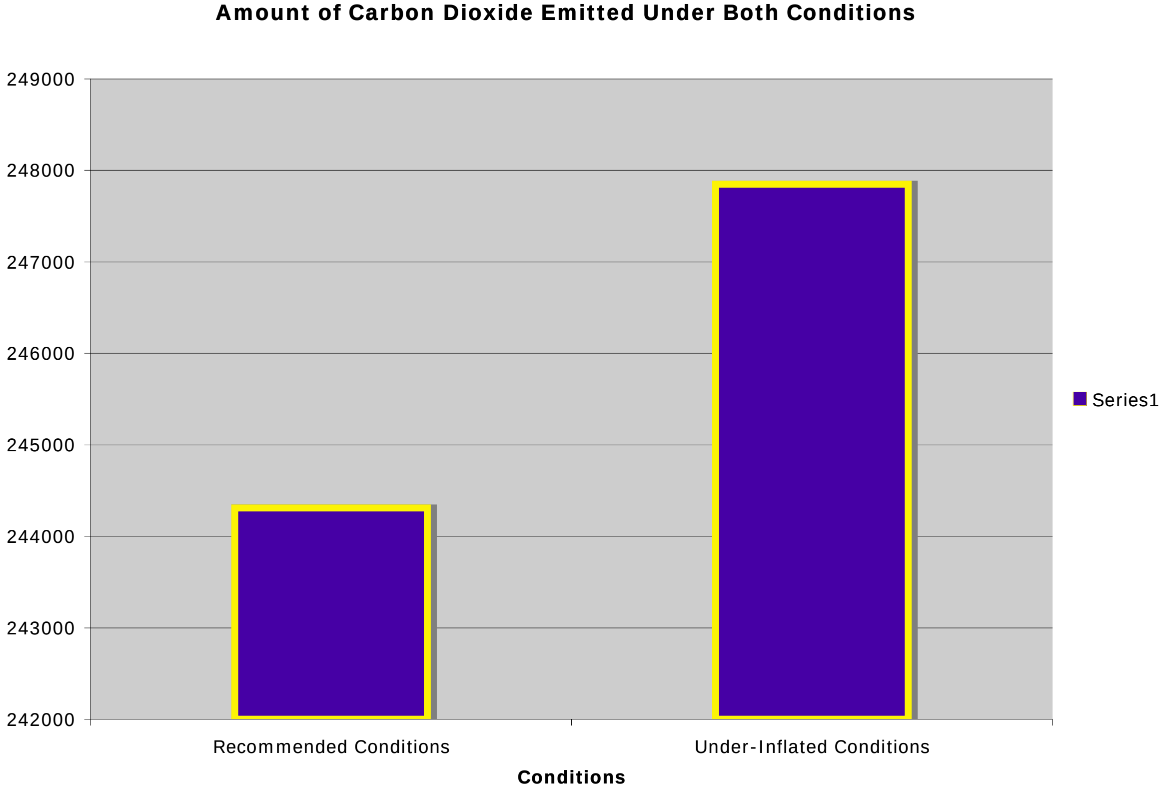
Appendix E: Graph shows the amount of money (in dollars) spent on gas each year for vehicles with observed under-inflation under recommended and under-inflated conditions (assuming that gas costs $2.75 per gallon). Notice how the differences appear to be rather insignificant for each vehicle.



Appendix F: Graph illustrates the total amount of money spent on gas each year for vehicles with observed under-inflation under recommended and under-inflated conditions (assuming that gas costs $2.75 per gallon). Notice that the differences look more significant when comparing totals.



Appendix G: Graph depicts the amount of CO_2 emitted each year by vehicles with observed under-inflation under recommended and under-inflated conditions (assuming that 19.4 pounds of CO_2 are emitted for every gallon of gas consumed).



Appendix H: Data Table: Vehicles with (overall) over-inflated tires sorted by overall difference in pounds per square inch between recommended conditions and observed, over-inflated conditions. Note: DS-F, DS-R, PS-F, and PS-R refer to driver's side and passenger's side front and rear tires.

Year	Make	Model	Recommended PSI (lbs)	EPA Estimated MPG	DS-F	DS-R	PS-F	PS-R	Overall Difference (PSI)
2000	FORD	F150	45, 45	14	45	45	45	46	1
2006	DODGE	GRAND CARAVAN	35, 35	17	36	36	35	35	2
2003	CHEVROLET	ASTRO	38, 38	14	40	38	40	37	3
2002	CHEVROLET	ASTRO	38, 38	14	38	40	41	39	6
2004	HONDA	CIVIC	35, 32	48	34	32	36	38	6
2006	Dodge	GRAND CARAVAN	35, 35	17	35	39	36	37	7
2007	TOYOTA	HIGHLANDER/HYBRID	32, 32	27	35	34	32	35	8
2006	FORD	ECONOLINE	55, 55	13	55	57	57	60	9
2004	GMC	SAVANA	55, 55	11	45	65	41	60	9
2008	TOYOTA	PRIUS	35, 33	48	35	37	39	37	12
2002	GMC	SAFARI	36, 36	12	42	39	40	38	15
2005	CHEVROLET	ASTRO	38, 38	14	44	42	40	42	16
2004	CHEVROLET	G1500	38, 38	15	43	43	42	42	18
2005	CHEVROLET	AVEO	30, 30	23	35	35	34	35	19
2004	TOYOTA	SIENNA	35, 35	17	40	40	39	41	20
2006	FORD	E-350	55, 55	14	58	64	57	64	23
2001	DODGE	CARAVAN	35, 35	17	42	41	41	40	24
	CHEVROLET	AVEO	30, 30	23	36	36	37	36	25
2005	TOYOTA	SIENNA LE	35, 35	17	42	45	40	40	27
	GMC	SAFARI	36, 36	12	41	46	43	42	28
2003	FORD	F450	70, 75	12	78	82	78	80	28
2007	GMC	SAVANNA	55, 55	11	62	62	62	62	28
2007	TOYOTA	SIENNA	35, 35	17	38	42	45	46	31
2009	Chevrolet	EXPRESS	55, 55	14	53	72	53	74	32
2008	TOYOTA	SIENNA	35, 35	17	43	44	42	45	34
2005	TOYOTA	CAMRY	32, 32	18	43	39	42	39	35
2006	GMC	SAVANA	55, 55	11	62	63	64	66	35
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2007	Ford	ECONOLINE E250	55, 55	13	66	67	63	67	43
2008	GMC	SAVANA	55, 55	11	55	79	52	78	44
2004	GMC	SAVANA	55, 55	11	59	75	60	75	49
2004	GMC	SAVANA	55, 55	11	62	74	65	68	49
2004	GMC	SAVANA	55, 55	11	60	72	61	77	50
2006	GMC	SAVANA	55, 55	11	75	64	73	62	54
2008	DODGE	SPRINTER	60, 60	26	68	79	70	78	55
2005	FORD	F350	55, 55	12	70	76	71	77	74
2009	FORD	E350	55, 55	14	78	80	80	78	96