Shift Schedule Model for Motorcycle Emissions & Fuel Economy Testing

Modeling Experience

- Worked on Harvard Fire Code incorporating specific subroutines to determine heat exchange through submarine walls for Electric Boat Corp
- Researched and wrote EPA's Nonroad Emissions Model
- Modeled effects on RVP of the mixing of various formulations of oxygenated gasoline
- Created a complex heat exchanger predictor model for vehicle exhaust
- Created a statistically driven motorcycle shift model

Background

- Presently, motorcycle manufactures are allowed to prescribe the shift schedule upon which they will operate their certificate text in the form of shift speeds 40 CFR 86-528-78
- In lieu of that, the tests can utilize the EPA's proscribed shift speed schedule
- The development of a model based on actual rider performance would provide for a more realistic representation of shift points

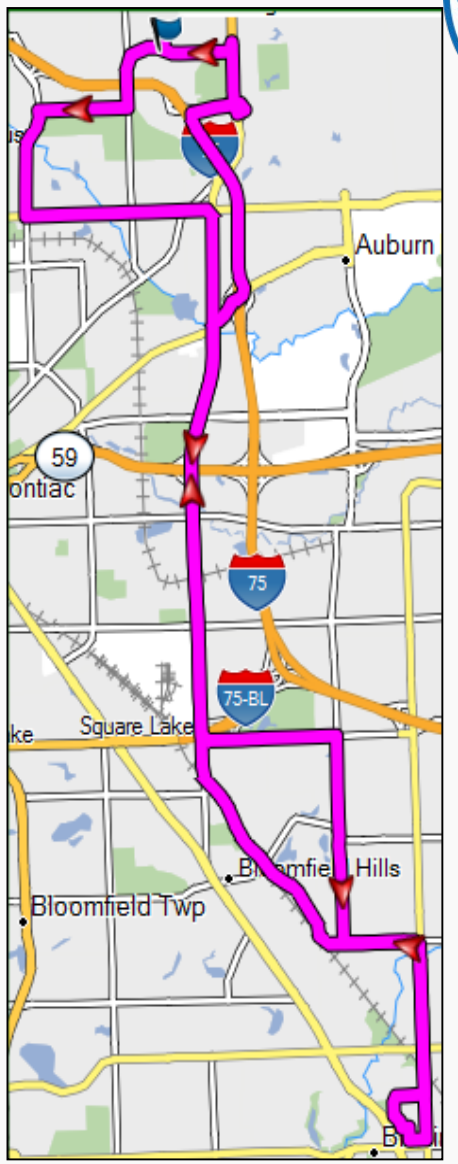
Procedure

- Motorcycle Road Testing
- Statistical Formulation
- Model Development
- Model Performance

Motorcycle Road Testing

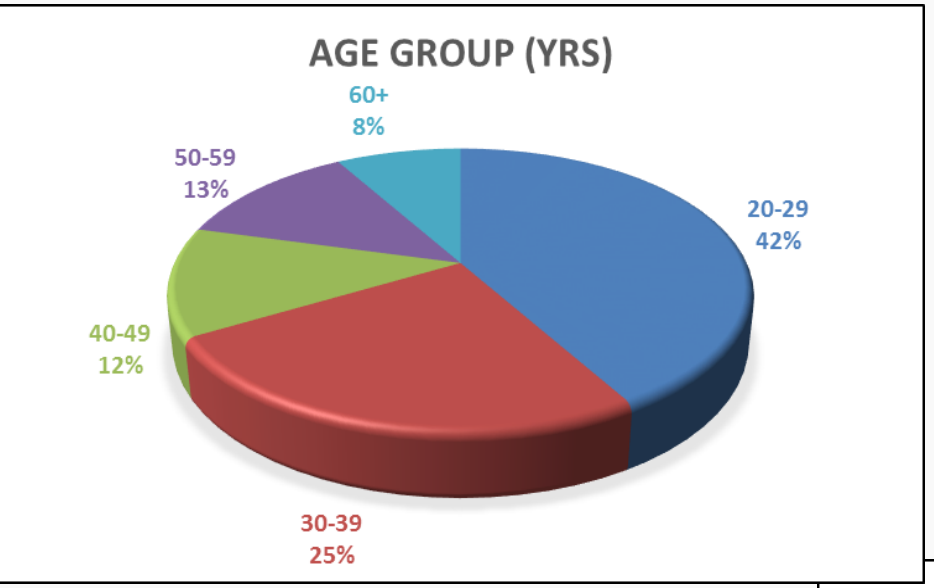
Route Statistics

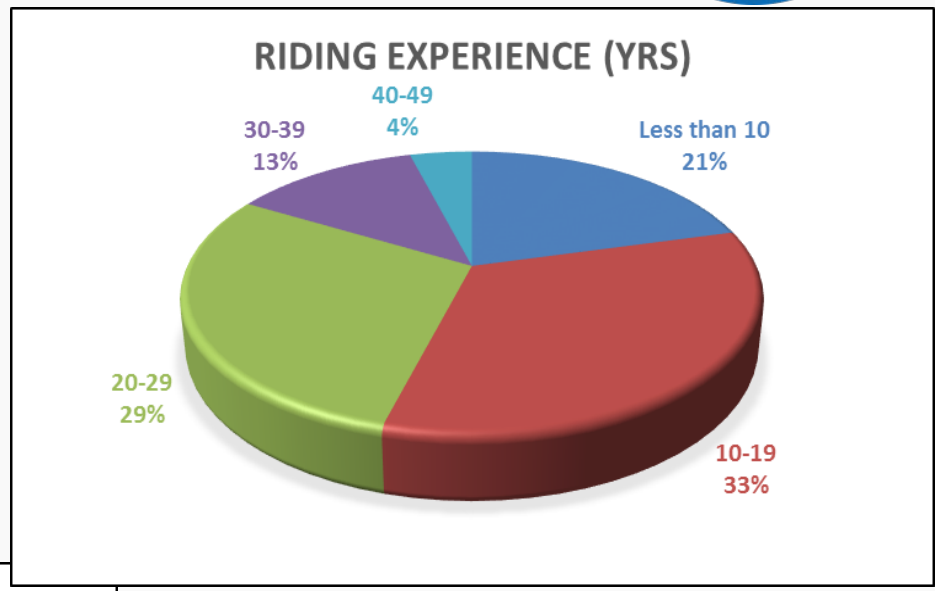
- 1.1 hour average total time
- 30.3 miles total distance
  - 1.8 miles of highway (mostly on and off ramp)
- 29 mph average speed
- 16-57 stops depending on traffic congestion and traffic light timing
  - 16 Stop Signs
  - 41 Traffic Lights
- 100 up-shift gear changes (average)

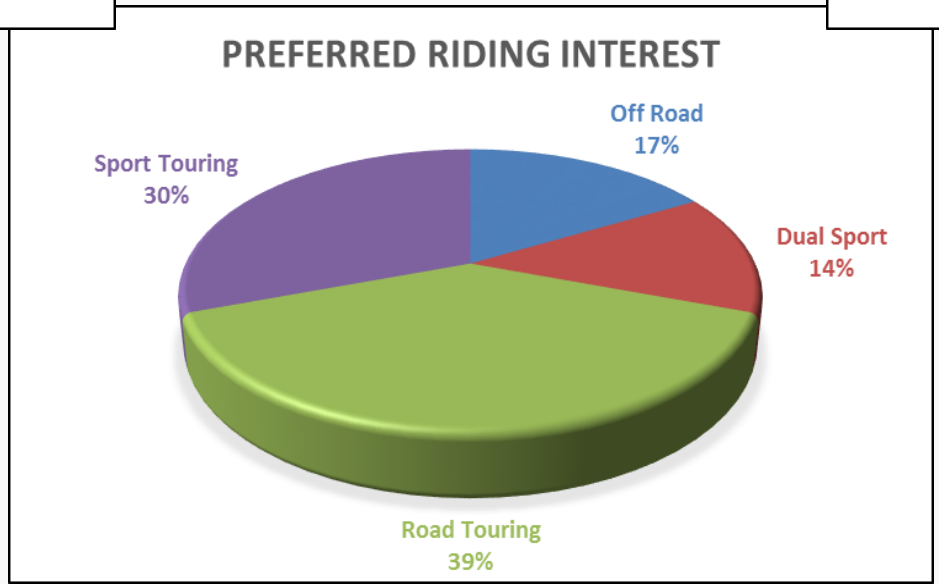


Motorcycle Road Testing

Driver Statistics – 26 Riders







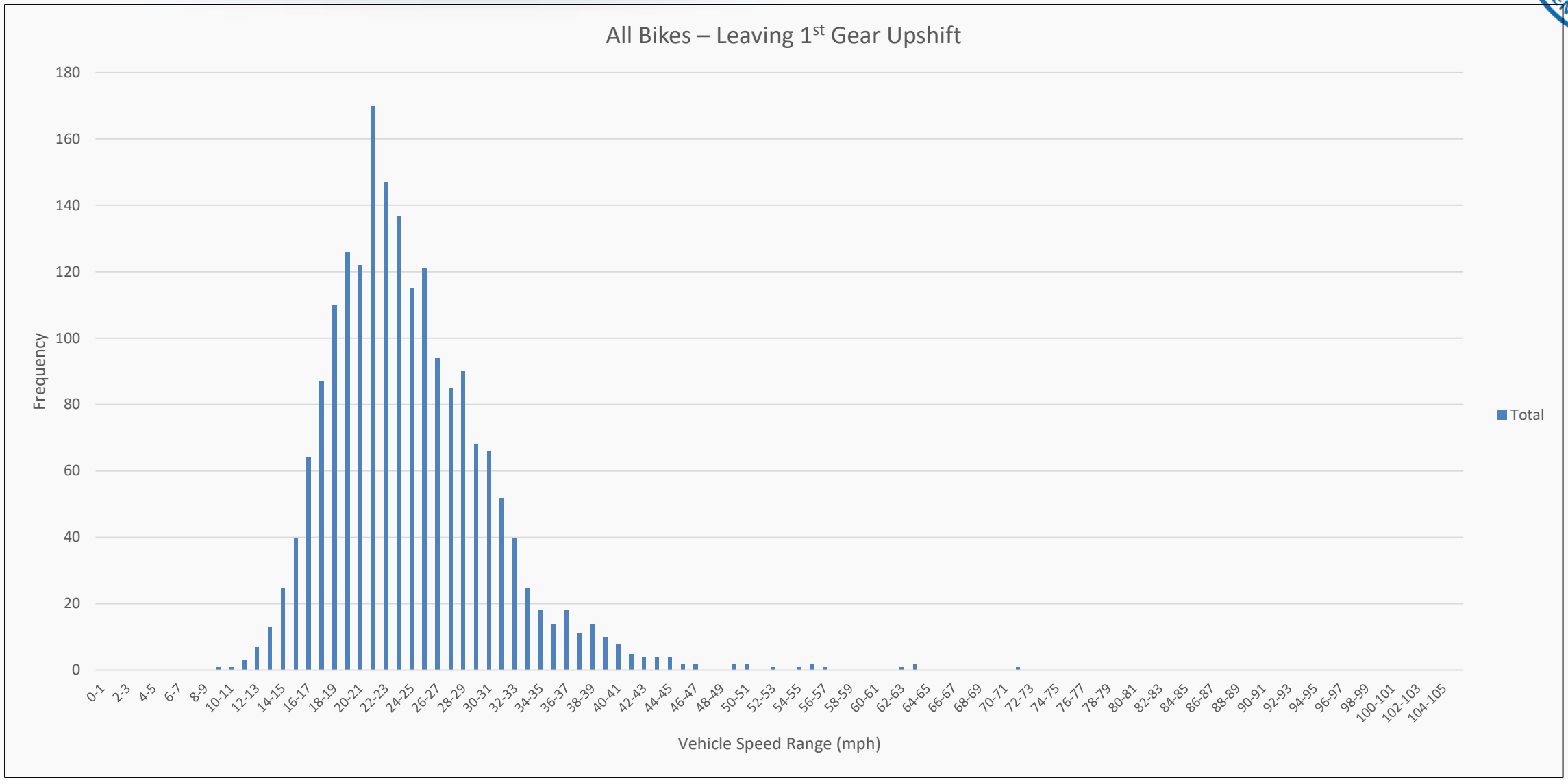
Parameters Collected

- Date
- Time
- Vehicle Speed (MPH) & (KPH)
- Engine Speed (rpm)
- GPS Latitude and Longitude
- Acceleration (mG)
- GPS Altitude
- Up Down Launch
- Leaving and Entering Gear (Gear #)
- Clutch Switch

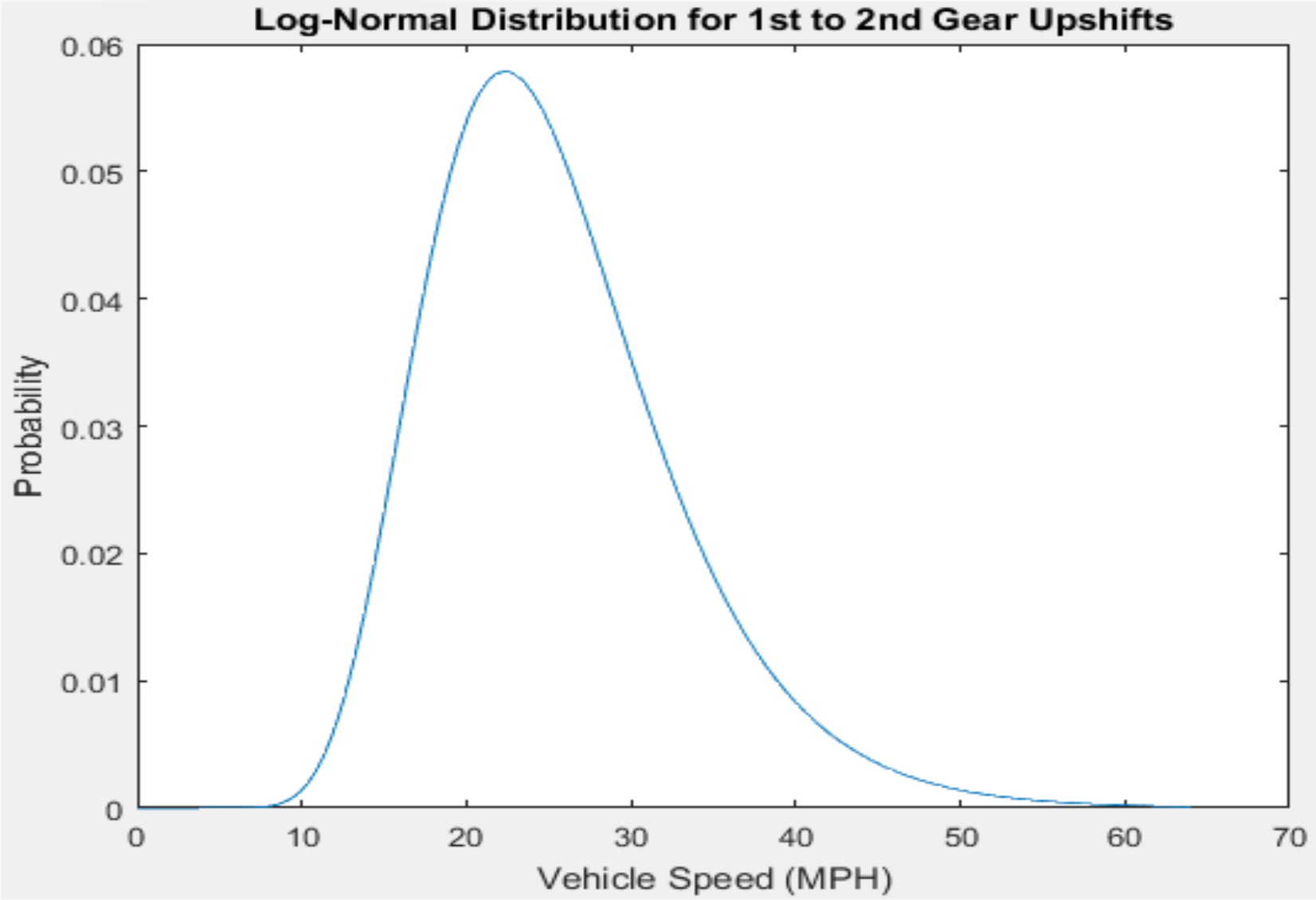
Model Operation

- Three types of motorcycles are represented
  - Cruiser
  - Sport
  - Standard
- Different sets of sample shift patterns were developed for each type of motorcycle
- Log Normal Curves were then derived from each of these sample shift patterns
- Different Log Normal Curves were determined for each shift and for each type of motorcycle (10 curves for each type)
  - Up-shift 1-2, 2-3, 3-4, 4-5, 5-6
  - Downshift 6-5, 5-4, 4-3, 3-2, 2-1

Sample Shift Pattern



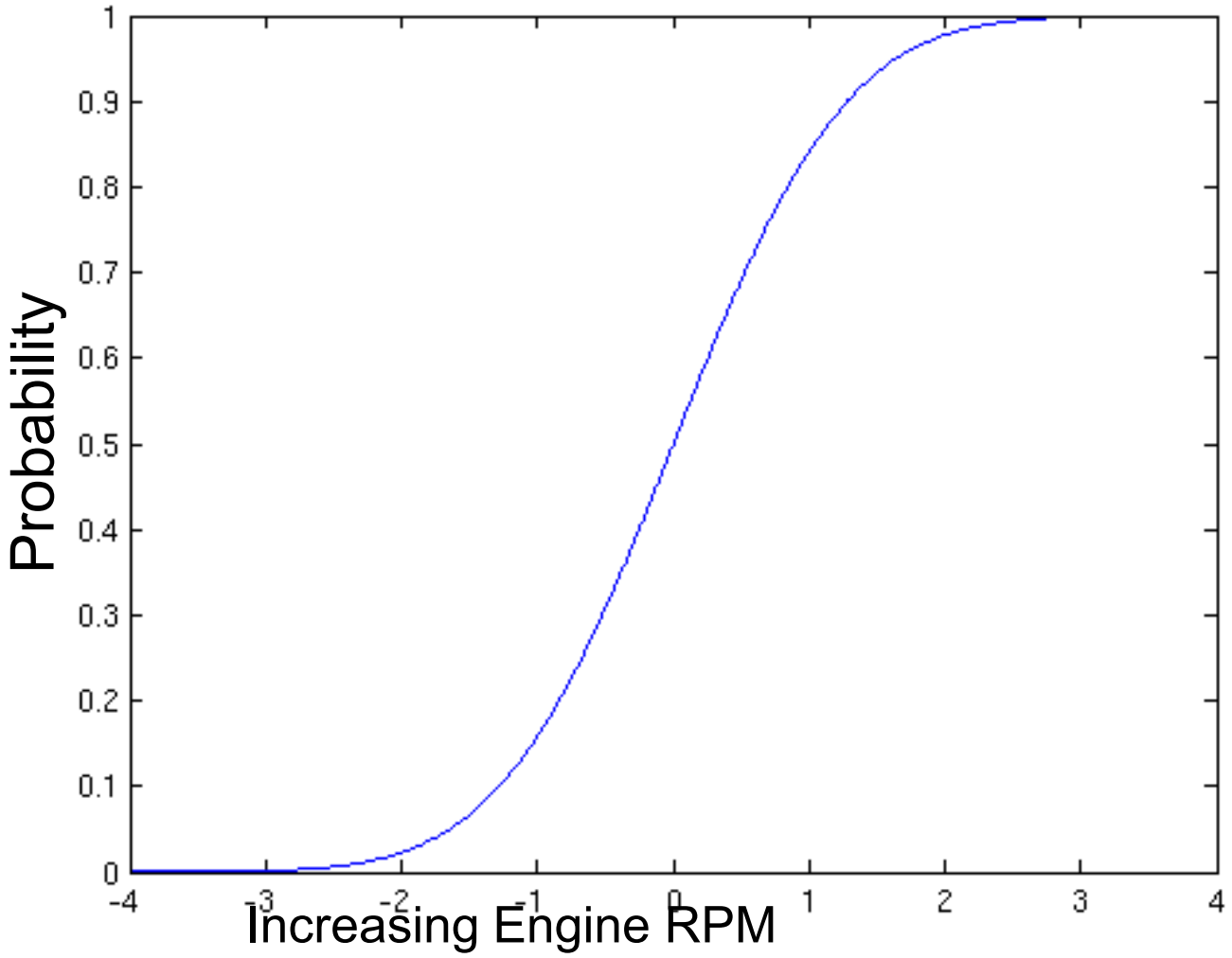
Example Log Normal Distribution



Model Operation

- The representative test cycle is selected (FTP, etc.)
- Log-Normal curves are converted into a cumulative distribution function (Page 12)
- Model steps through each speed point incrementally and consults the distribution function to determine if a shift will take place
  - As expected, the probability of a shift will increase with each unsuccessful shift increment
  - Shifts will occur both up or down based on whether the test cycle indicates that the motorcycle is speeding up or slowing down

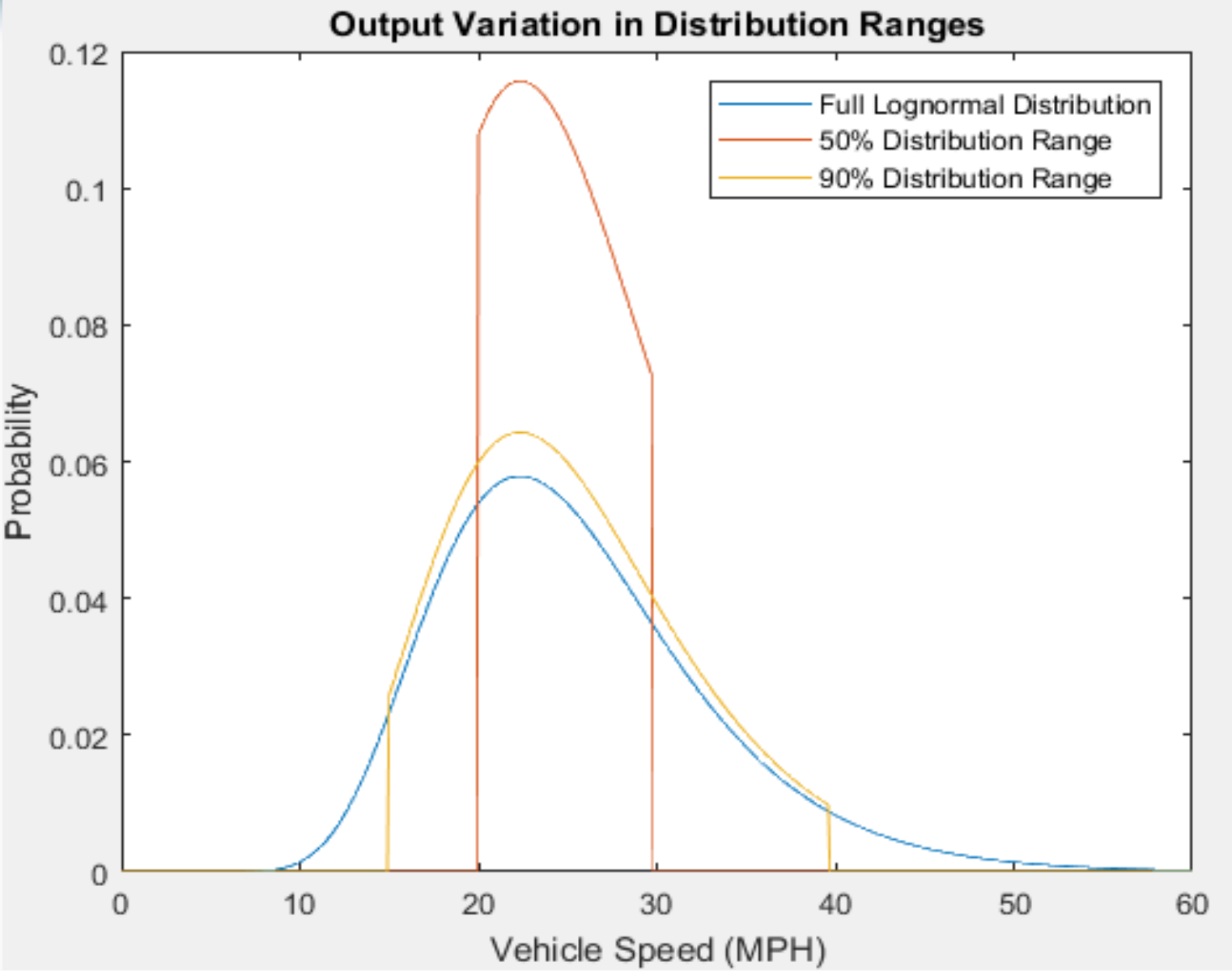
Illustration of Typical Cumulative Distribution Function



Model Options

- Operation of the model using the full probability can result in very different shift patterns for the same test procedure
- While these are viable options efforts were made to mitigate the broad range probability effects while retaining the flexibility of the model
  - The ability to limit the rage of the distribution was added
  - This allows the user to designate a percentage of the distribution range centered around the mean
  - 100% (full range) to 1% (narrowest range – no variation)
  - Page 14 shows an example

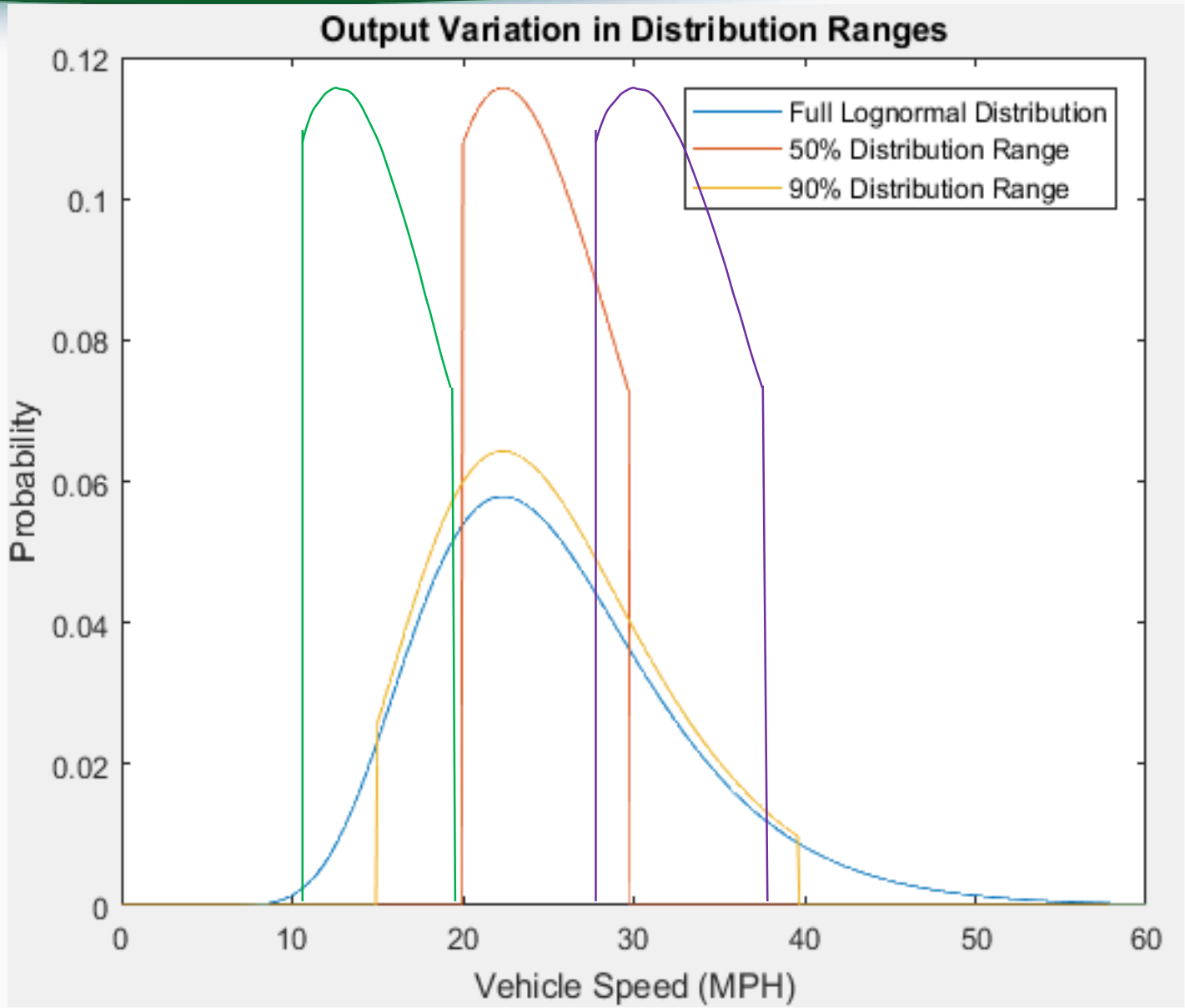
Distribution Range Example



Shifting of the Mean in the Output Distribution Range

- In order to utilize the ability to limit the distribution range and to further refine the model to allow representation of:
  - Aggressive Riders – mean shift to higher RPM
  - Average Riders – mean remains the same
  - Conservative Riders – mean shifted to lower RPM
- In order to perform this the “effective mean is shifted and the distribution is narrowed accordingly

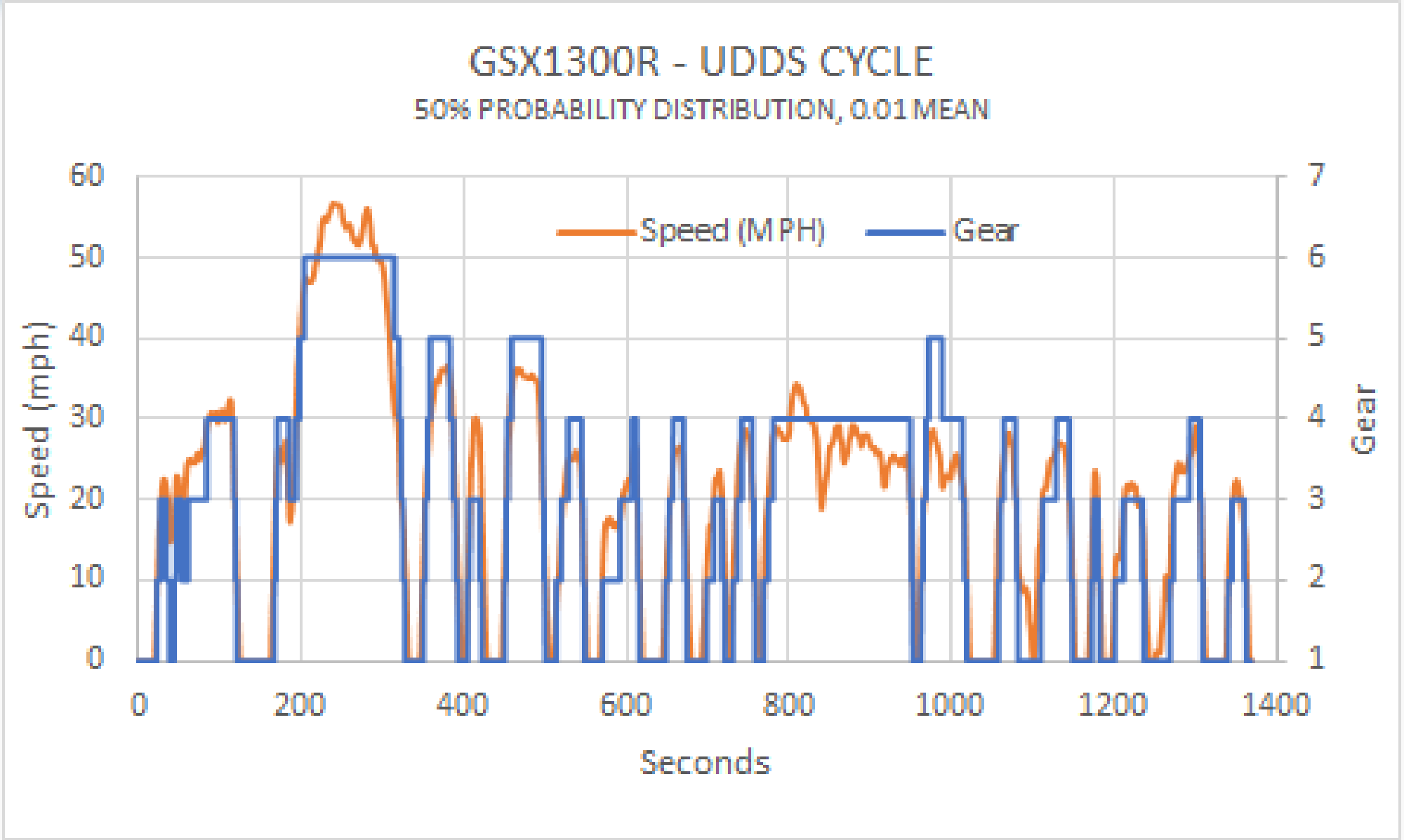
Representation of Mean Shift in the Distribution Range



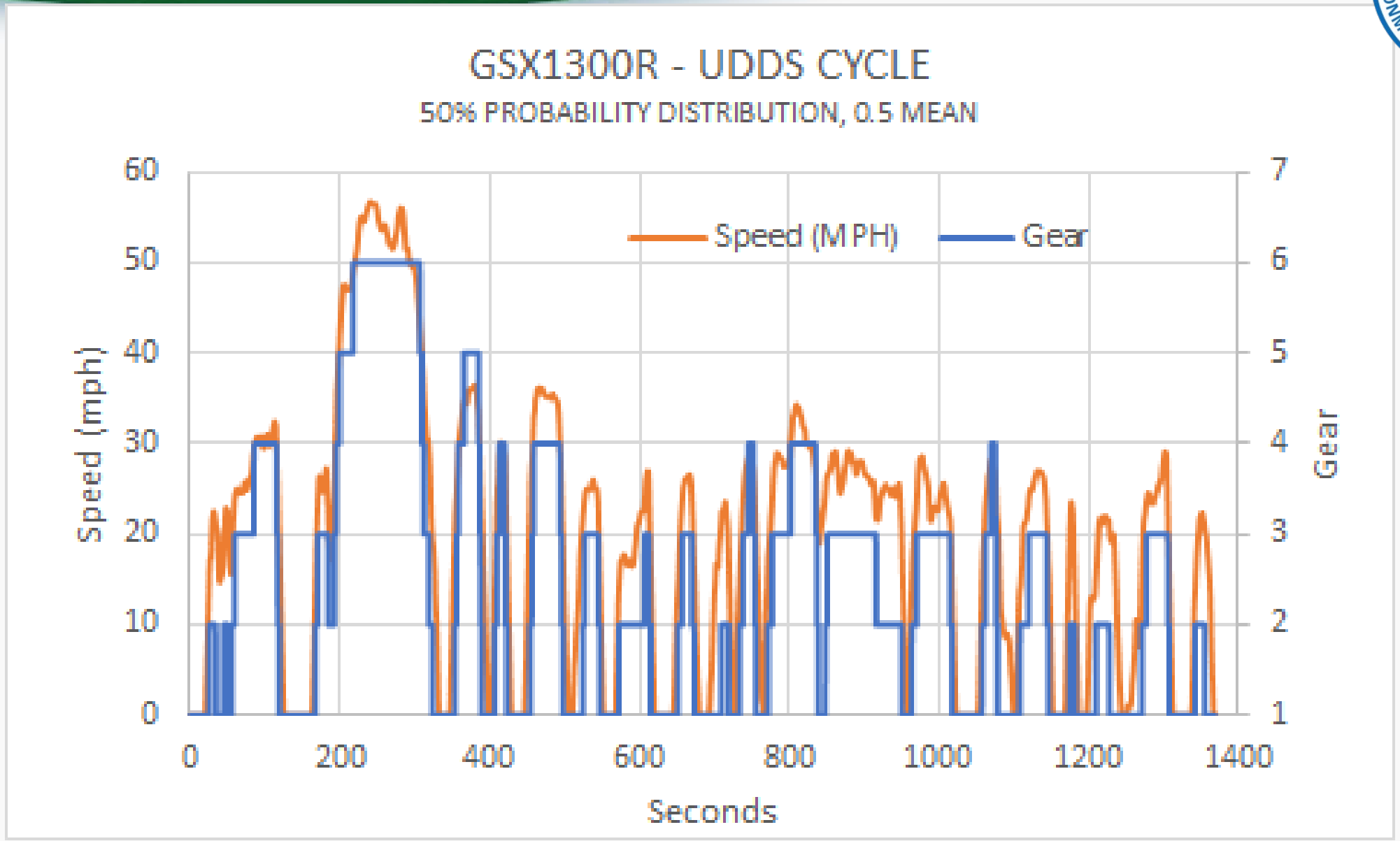
Model Input

Input	
Type of Motorcycle	Sport, Cruiser, Standard
Idle RPM	1200
Red Line RPM	12000
Primary Drive Ratio	1.6
Final Drive Ratio	2.4
1st Gear Ratio	2.55
2nd Gear Ratio	1.9
3rd Gear Ratio	1.45
4th Gear Ratio	1.2
5th Gear Ratio	1.1
6th Gear Ratio	.98
Tire Size	180/50ZR17M

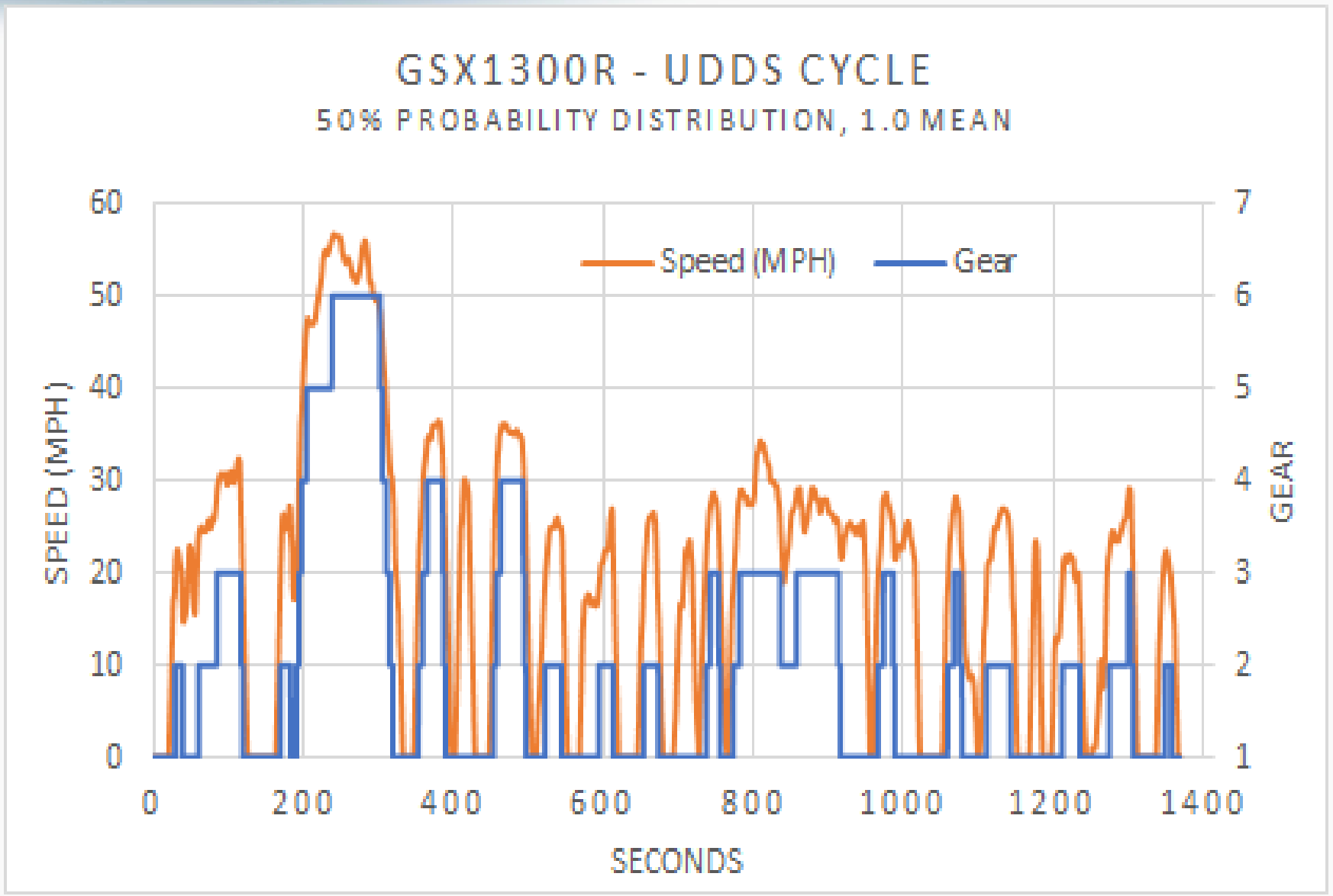
Sample Output
Conservative Rider



Sample Output
Average Rider



Sample Output
Aggressive Rider



Real World Shifting Comparison

- Both EPA (FTP) and WMTC perform upshifts and downshift at the same speed
- A Real Rider (RWDC) will not upshift and down shift at the same speed
  - Creates a more realistic scenario
  - Model operates in this manner

Drive Cycle	Gear	Shift Speed (km/h)			
		FTP	WMTC		RWDC
			Acc/Dec	Cruise	
Motorcycle A	1→2	30	23.1	11.6	24
	2→3	45	42	23.1	44
	3→4	60	53.3	42.0	67
	4→5	75	64.6	53.3	82
	5→6	N/A	75.7	64.6	107
	6→5	N/A	64.6		83
	5→4	75	53.3		52
	4→3	60	42		44
	3→2	45	23.1		28
	2→1	N/A	11.6		15
	Declutch	15	10		10
Motorcycle B	Gear	FTP	WMTC		RWDC
			Acc/Dec	Cruise	
	1→2	30	29.7	16.9	31
	2→3	45	50.4	29.7	45
	3→4	60	68.6	50.4	58
	4→5	75	85.4	68.6	71
	5→6	N/A	99.6	85.4	81
	6→5	N/A	85.4		73
	5→4	75	68.6		58
	4→3	60	50.4		46
	3→2	45	29.7		30
	2→1	N/A	16.9		19
	Declutch	15	12.4		10
Motorcycle C	Gear	FTP	WMTC		RWDC
			Acc/Dec	Cruise	
	1→2	30	30.3	22.5	31
	2→3	45	54.1	30.3	52
	3→4	60	69.9	54.1	69
	4→5	75	87.4	69.9	81
	5→6	N/A	98.6	87.4	111
	6→5	N/A	87.4		76
	5→4	75	69.9		59
	4→3	60	54.1		49
	3→2	45	30.3		37
	2→1	N/A	22.5		23
	Declutch	15	15.9		10

Model - Important Distinctions

- Uses three distinct motorcycle design options which will provide different results
- Will not require a given upshift or downshift at the same speed during a given test
- Will not require downshift at the same speed as its analogous upshift
- Model could be utilized to make comparisons between manufacturer shift schedules and various riding styles