Black Belt Six Sigma Project Summary

Name of project: __Fuel Economy and Miles per Gallon Metric Testing
Submitted by: __Mike Roeback, Brad Manes, and Tina Fowler_____
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Date submitted: _12__/_12__/__2011_

I. Project Selection Process

Item	Yes	No	Comments
Key business issue	X		Accurately calculate Fuel Usage per MPG for Fuel Economy Testing
Linked to a define process	X		Type 2 FE Testing
Customers identified	X		Navistar Management and Industry Standards
Defects clearly defined	X		34.78% Waste
Estimated cost savings	X		Approx. 90k per year

This project was selected because of the high cost of waste associated with it.

II. Project Overview and Summary

Thought we didn't meet our 90% process capability improvement, we managed to improve it 63.7%, which moved our P&D Fuel Economy testing process from a Cp of 0.65 to 1.02. We got a huge gain but there is still plenty of room for more improvement.

III. Approvals

	Name	*Signature*	*Date*
Project Leader	Mike Roeback		10/15/2011
Champion	Navistar Management and Proving Grounds		10/15/2011
Process Owner	Tina Fowler		10/15/2011
Engineer	Brad Manes		10/22/2011

Black Belt Project Charter

Project Title		
Date Charted	Target Completion Date	Actual Completion Date
9/22/2011	December 12, 2011	
Project Leader	Team Facilitator	Team Champion
Mike Roeback	Tina Fowler	Proving Ground and Navistar Management
Estimated Cost Savings	Actual Cost Savings	Costs of implementing project
90K per yr.	Unknown as of yet.	$4,650

Participating Green Belts

Brad Manes
Tina Fowler
Mike Roeback

Other Team Members

Valerie Bratten

Problem Statement

How can Navistar Fuel Economy team accurately calculate fuel usage to improve Fuel Economy Testing?

Project Goal, Objective, and Metrics

3 cycles ran within 2% of each other will be accepted as our true Fuel Economy.

Describe the output ("Y") **and the scope**

Accurately calculate Fuel Usage (Miles Per Gallon \ MPG) for improved Fuel Economy (FE) testing.

Describe the process that will be investigated

Two trucks,
One Control truck, known as "A" (will stay the same throughout the test)
One test truck, known as "B" (will be modified throughout the test)

Inspect both trucks
Tire size, type and tread depth
Instrument both truck for EDAQ

Run trucks together (15 seconds apart +/- 5 seconds), swap lead & follow vehicle half way through a test cycle.

Fuel meters are installed in line between the stock truck fuel tank & the engine. The data from the fuel meter will be recorded by the EDAQ system.

Two types of test to perform
P & D (pick-up & delivery) to simulate city driving 6 segments per fuel fill cycle
Steady State to simulate highway driving 150 miles (approx.) per fill cycle

Every cycle, miles ran will be divided by gallons of fuel used to determine our MPG. Majority of cycles ran (must compare within 2% of each other, truck to truck) will be accepted as our true MPG.

Describe the challenges and support required

See Attached Financial Argument.

Project Schedule

D1. Select the output characteristic. Date:10/15/11

Criteria:
Is there a measurable output? Yes. The output can be measured by calculating the Miles Per Gallon between two trucks.
Is there a performance standard for the output? 2%
Does variation currently exist? Yes
Is there a process associated with the problem? Yes
Is the solution unknown? Yes

D2. Define the output performance standard. Date:10/15/11

Valid T/C ratios must fit within a 2% band. The 2% band means that the lowest T/C ratio cannot be more than 2% below the highest.

D3. Describe the process. Date:10/22/11
Required tools: Detailed process map, FMEA

To provide a standardized procedure for comparing in-service fuel consumption of two conditions of a test vehicle. The test results for this procedure is the percent difference in fuel consumption between the Test Vehicle and the Baseline Vehicle or the difference in fuel consumption of one Test Vehicle in two different test conditions.

Uncontrolled variables that affect fuel consumption act on both the test and control

vehicles in such a way that any influence on T/C ratio is effectively cancelled.

T/C Ratio — A T/C ratio is the ratio of the quantity of fuel consumed (data point) by the test vehicle to the quantity of fuel consumed (data point) by the control vehicle during one test run.

All vehicles perform consistently enough that a population of data will produce just one valid segment (of three T/C ratios within a 2% band).

Baseline Segment — A baseline segment is the average of a minimum of three valid T/C ratios. A baseline segment establishes baseline fuel consumption of test vehicles or the first of two vehicles to be tested.

Test Run — A test run is a complete circuit of the test route. A test run always starts and ends at a common point. This may be accomplished by using either a closed loop of highways or a single highway with one-half of the test run outbound, a turn-around point, and one-half of the test inbound, or a test track should this be used. Each vehicle test run generates one data point.

Leg – A portion of a test run that is used to represent a group of commonly repeated elements or route descriptions, that can be repeated once or several times to incorporate an entire test run.

Test Segment — A group of test runs that are performed with vehicles in a specified configuration. A test segment is also the average of a minimum of three valid T/C ratios. A test segment establishes the fuel consumption of the test vehicle after modification or the fuel consumption of the second of two vehicles tested. A valid test segment must be compared to a valid baseline segment.

Two trucks,
One Control truck, known as “A or C” (will stay the same throughout the test)
One Test truck, known as “B or T” (will be modified throughout the test)

Inspect both trucks
Tire size, type and tread depth
Instrument both truck for EDAQ

Run trucks together (15 seconds apart +/- 5 seconds), swap lead & follow vehicle half way through a test cycle.

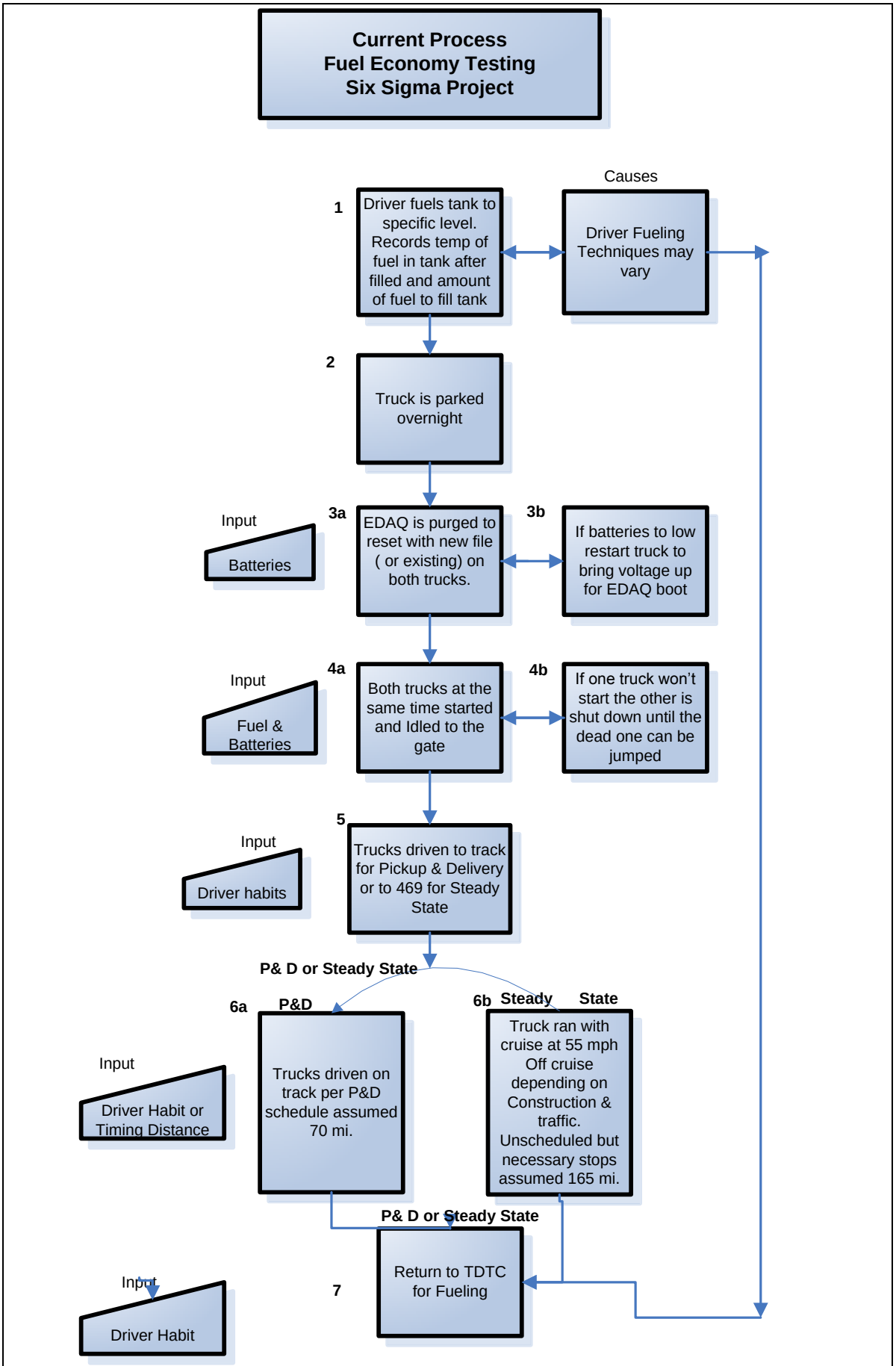
Fuel meters are installed inline between the stock truck fuel tank & the engine. The data from the fuel meter will be recorded by the EDAQ system. Tank fill information will also be tracked as a secondary means of measurement.

Trucks will run a cycle then be brought back to a designated filling area after cycle is completed. At that point, trucks will be filled using the Steve Stick method, recording volume used, and fuel temp after fill and miles ran.
Pre & Post fill templates will be used to calculate density of fuel, therefore, adjusting our

filled fuel measurement

Two types of test to perform
P & D (pick-up & delivery) to simulate city driving 6 legs per fuel fill cycle
Steady State to simulate highway driving 150 miles (approx.) per fill cycle

Miles ran will be divided by gallons of fuel used to determine our MPG every cycle.


Current Process
Fuel Economy Testing
Six Sigma Project
Causes
1
Driver fuels tank to specific level. Records temp of fuel in tank after filled and amount of fuel to fill tank
Driver Fueling Techniques may vary
2
Truck is parked overnight
Input
Batteries
3a
EDAQ is purged to reset with new file (or existing) on both trucks.
3b
If batteries to low restart truck to bring voltage up for EDAQ boot
Input
Fuel & Batteries
4a
Both trucks at the same time started and Idled to the gate
4b
If one truck won't start the other is shut down until the dead one can be jumped
5
Input
Driver habits
Trucks driven to track for Pickup & Delivery or to 469 for Steady State
P& D or Steady State
6a
P&D
6b
Steady
State
Input
Driver Habit or Timing Distance
Trucks driven on track per P&D schedule assumed 70 mi.
Truck ran with cruise at 55 mph Off cruise depending on Construction & traffic. Unscheduled but necessary stops assumed 165 mi.
P& D or Steady State
7
Return to TDTC for Fueling
Input
Driver Habit

M1. Validate the measuring system. Date:

Required tools: Gage R&R/Attribute Agreement Analysis

First Problem Found!

First fuel meter was only accurate within 1.5% sucking up 75% of our 2% total customer spec.

The second meter is better @ .6% accuracy but still consuming 33.3% of our total spec.

Fuel meters are determined Not Capable!

Plan "B" –the alternate fuel measuring system

Fill both trucks at pumps using Steve Stick Method & record results after re-measuring in a controlled environment.

Both Drivers Filling Both Trucks

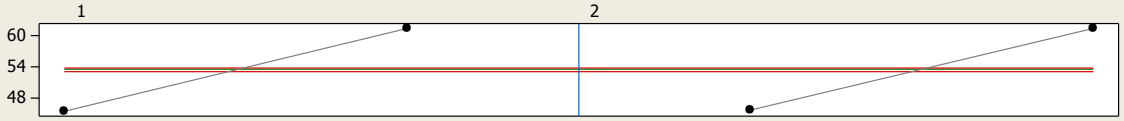
↓	C1	C2-T	C3	C4	C5	C6	C7
	Driver	Truck	MM tank filled from top	Gallons tank filled to	Difference from ideal	Avg. fuel used per run	error per fill
1	1	A	76	45.50	0.00	7.833	0.00%
2	1	A	77	45.38	-0.12	7.833	-1.53%
3	1	A	77	45.38	-0.12	7.833	-1.53%
4	1	A	75	45.62	0.12	7.833	1.53%
5	1	A	76	45.50	0.00	7.833	0.00%
6	2	A	77	45.38	-0.12	7.833	-1.53%
7	2	A	74	45.74	0.24	7.833	3.06%
8	2	A	74	45.74	0.24	7.833	3.06%
9	2	A	73	45.86	0.36	7.883	4.57%
10	2	A	79	45.14	-0.36	7.833	-4.60%
11	1	B	78	61.08	-0.30	7.711	-3.89%
12	1	B	74	61.68	0.30	7.711	3.89%
13	1	B	77	61.23	-0.15	7.711	-1.95%
14	1	B	75	61.53	0.15	7.711	1.95%
15	1	B	74	61.68	0.30	7.711	3.89%
16	2	B	78	61.08	-0.30	7.711	-3.89%
17	2	B	76	61.38	0.00	7.711	0.00%
18	2	B	77	61.23	-0.15	7.711	-1.95%
19	2	B	75	61.53	0.15	7.711	1.95%
20	2	B	74	61.68	0.30	7.711	3.89%

Measurement System Analysis

Gage R&R Study for Gallons tank filled to Variation Report

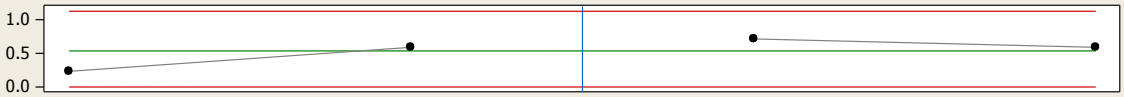
Xbar Chart of Part Averages by Operator

At least 50% should be outside the limits. (actual: 100.0%)



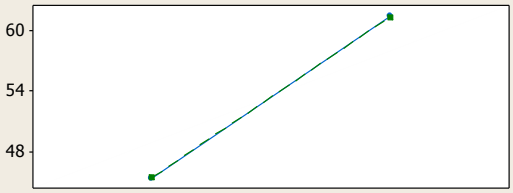
R Chart of Test-Retest Ranges by Operator (Repeatability)

Operators and parts with larger ranges have less consistency.



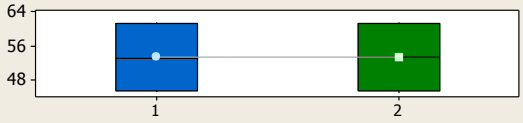
Reproducibility — Operator by Part Interaction

Look for abnormal points or patterns.



Reproducibility — Operator Main Effects

Look for operators with higher or lower averages.



Variation Breakdown

Source	StDev	%Process (data)
Total Gage	0.237	2.11
Repeatability	0.237	2.11
Reproducibility	0.000	0.00
Part-to-Part	11.233	99.98
Process Var (data)	11.235	100.00

Gage R&R Study for Gallons tank filled to Summary Report

Can you adequately assess process performance?

2.1% of all process variation can be attributed to the measurement system. The process variation is estimated from the parts in the study.

Study Information

Number of parts in study	2
Number of operators in study	2
Number of replicates	5

(Replicates: Number of times each operator measured each part)

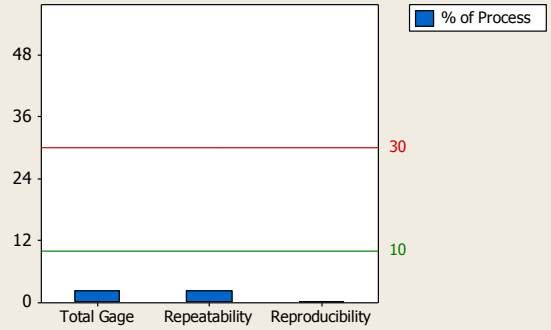
Comments

General rules used to determine the capability of the system:
<10%: acceptable
10% - 30%: marginal
>30%: unacceptable

Examine the bar chart showing the component contributions, and use this information to guide improvements:
-- Test-Retest component (Repeatability): The variation that occurs when the same person measures the same item multiple times. This accounts for 100.0% of the measurement variation. It is 2.1% of the total variation in the process.
-- Operator component (Reproducibility): The variation that occurs when different people measure the same item. This accounts for 0.0% of the measurement variation. It is 0.0% of the total variation in the process.

Variation Breakdown

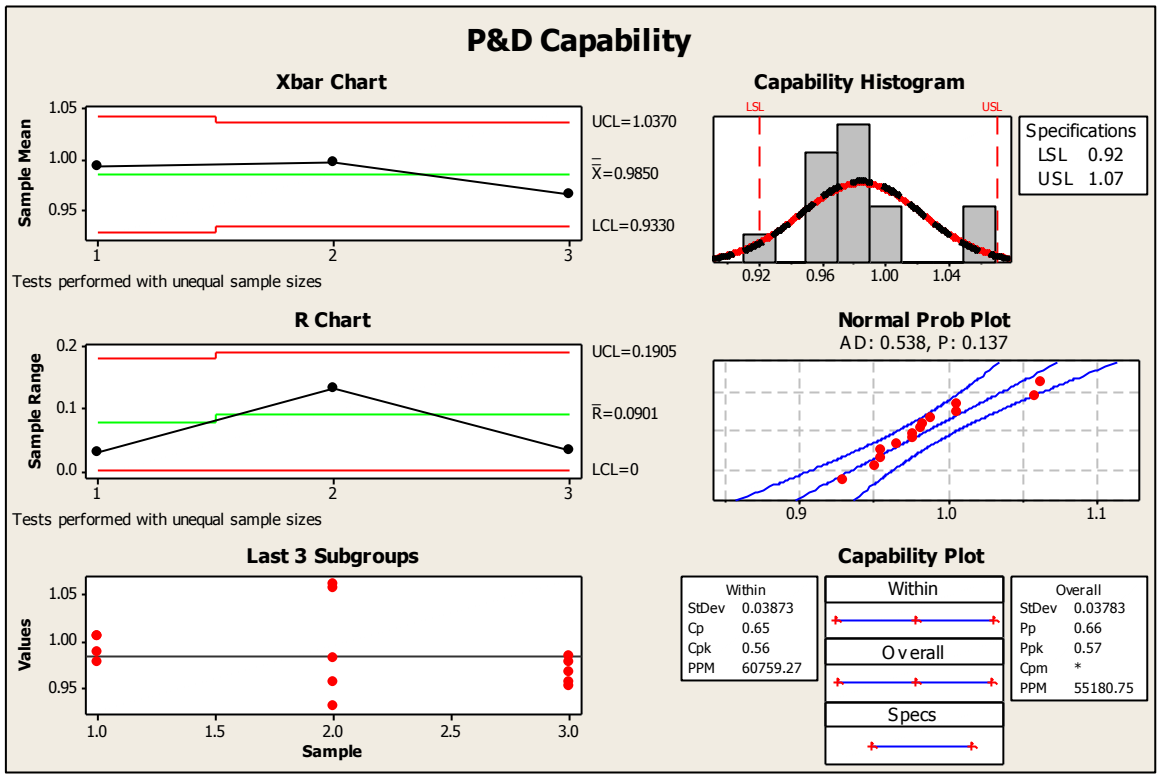
Is there a problem with repeatability or reproducibility?



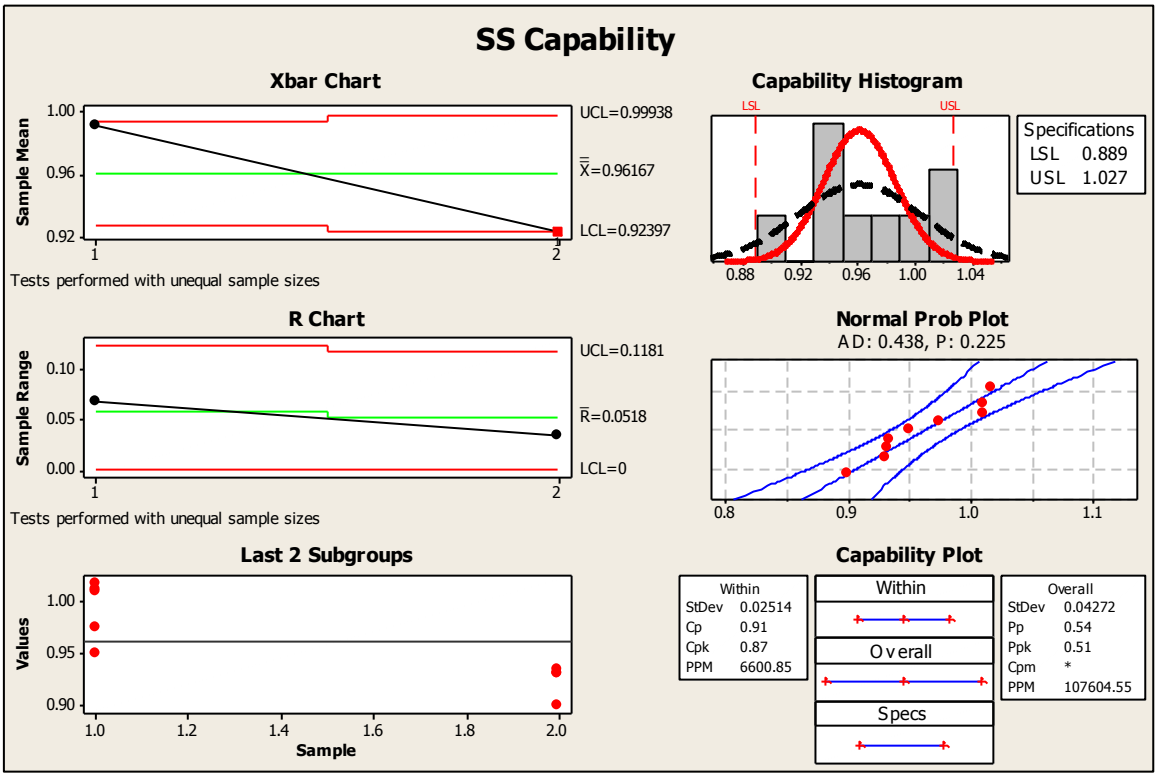
Fueling Gage R&R Passed

M2. Establish current process capability for the output. Date:
Required tools: Capability six pack, Control charts

↓	C1-T	C2	C3	C4	C5	C6	C7-T	C8
	Test Type	Fuel Fill A	Fuel Fill B	Mileage	MPG A	MPG B	Calibration	T/C Ratio
1	P&D	7.979	7.888	70	8.773	8.874	Baseline	0.98860
2	P&D	7.931	7.971	70	8.826	8.782	Baseline	1.00504
3	P&D	8.982	8.767	70	7.793	7.984	Baseline	0.97606
4	P&D	6.644	6.684	70	10.536	10.473	Baseline	1.00602
5	P&D	8.169	8.022	70	8.569	8.726	Cal 1	0.98201
6	P&D	8.230	8.736	70	8.505	8.013	Cal 1	1.06148
7	P&D	6.940	7.337	70	10.086	9.541	Cal 1	1.05720
8	P&D	8.152	7.574	70	8.587	9.242	Cal 1	0.92910
9	P&D	8.037	7.672	70	8.710	9.124	Cal 1	0.95459
10	P&D	7.890	7.754	70	8.872	9.028	Cal 2	0.98276
11	P&D	8.065	7.872	70	8.679	8.892	Cal 2	0.97607
12	P&D	7.159	6.910	70	9.778	10.130	Cal 2	0.96522
13	P&D	7.875	7.525	70	8.889	9.302	Cal 2	0.95556
14	P&D	7.614	7.236	70	9.194	9.674	Cal 2	0.95035



↓	C1-T	C2	C3	C4	C5	C6	C7-T	C8
	Test Type	Fuel Fill A	Fuel Fill B	Mileage	MPG A	MPG B	Calibration	T/C Ratio
1	SS	17.912	18.094	165	9.212	9.119	Cal 1	1.01016
2	SS	19.178	18.689	165	8.604	8.829	Cal 1	0.97450
3	SS	19.143	18.186	165	8.619	9.073	Cal 1	0.95001
4	SS	17.783	18.084	165	9.279	9.124	Cal 1	1.01693
5	SS	17.966	18.135	165	9.184	9.098	Cal 1	1.00941
6	SS	19.442	17.482	165	8.487	9.438	Cal 2	0.89919
7	SS	17.700	16.467	165	9.322	10.020	Cal 2	0.93034
8	SS	18.017	16.824	165	9.158	9.807	Cal 2	0.93378
9	SS	17.532	16.318	165	9.411	10.112	Cal 2	0.93076



M3. Determine project objectives. Date:

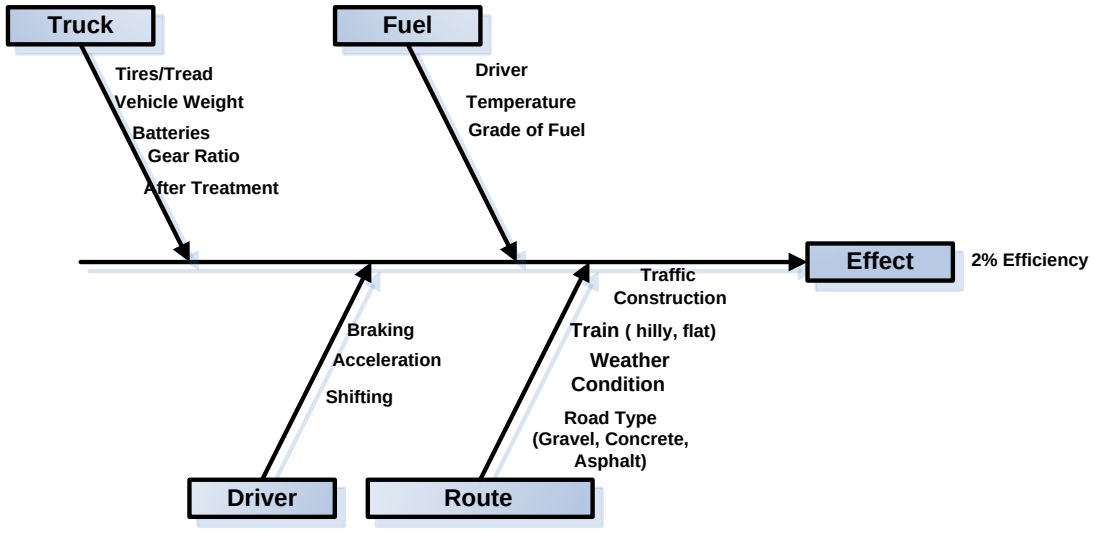
Our Current Cp for Steady State FE test process is 0.91 which is much better than the Cp of our Pick-up & Delivery FE test process of 0.65. We will be concentrating on the P&D portion of our FE test since it's the less capable of the two.

The goal is a 90% increase in capability for an improved Cp of 1.235.

Once we have improved our Cp we can look at shifting the process closer to the Upper or Lower Spec Limit to increase our Cpk.

A1. Identify and list all potential causes (inputs). Date: 12/13/11

Required tools: Process map, Brainstorming, Fishbone diagram, FMEA, Cause and effect matrix, Potential "X" matrix



A2. Screen potential causes. Date: 12/7/11

Required tools: See A1

Screened through all input with test engineers to target key inputs for grading by Power Train Group. They will grade on a scale of 1 to 5.
1 = to no effect on Type 2 FE testing
2 = slight effect
3 = moderate effect
4 = great effect
5 = absolute effect

Key inputs:

Fuel Fill Method
Driving Route
Braking Techniques
Acceleration Techniques
Weather Conditions
Vehicle Condition

***** Grade with an "X" the Key Inputs according to their on Type II Fuel Economy Testing *****

GRADE CARD

Key Inputs	No Effect 1	Slight Effect 2	Moderate Effect 3	Grade Effect 4	Absolute Effect 5
Fuel Fill Method					
Driving Route					
BrakingTechniques					
AccelerationTechniques					
Weather conditions					
Vehicle Condition					

A3. Determine the f(x) – key input variable(s) Date: 12/12/11

Required tools: Hypothesis testing, Correlation, Regression, Design of experiments

Ran Chi-Square test to analysis the data collected.

↓	C1-T	C2	C3	C4	C5	C6	C7
	Person	Fuel Fill	Route	Braking	Accelerating	Weather	Vehicle
1	A	5	2	1	3	4	4
2	B	5	1	4	4	3	5
3	C	5	2	3	4	1	2
4	D	2	3	4	4	1	5
5	E	4	1	1	1	4	3
6	F	5	2	2	4	3	4

Chi-Square Test for Association: Person by Factors
Diagnostic Report

Observed and Expected Counts

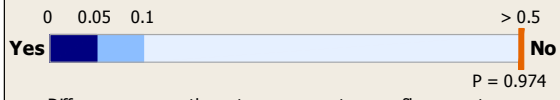
	Fuel Fill		Route		Braking		Accelerating		Weather		Vehicle	
	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp
A	5	4.5	2	1.9*	1	2.6	3	3.4	4	2.7	4	3.9
B	5	5.2	1	2.2	4	3.0	4	4.0	3	3.2	5	4.6
C	5	4.0	2	1.7*	3	2.3	4	3.1	1	2.5	2	3.5
D	2	4.5	3	1.9*	4	2.6	4	3.4	1	2.7	5	3.9
E	4	3.3	1	1.4*	1	1.9*	1	2.5	4	2.0	3	2.9
F	5	4.7	2	2.0*	2	2.7	4	3.6	3	2.9	4	4.1
Total	26		11		15		20		16		23	

* Indicates a violation.

Expected counts should be at least 2 to ensure the validity of the p-value for the test.

Chi-Square Test for Association: Person by Factors
Summary Report

Do the percentage profiles differ?



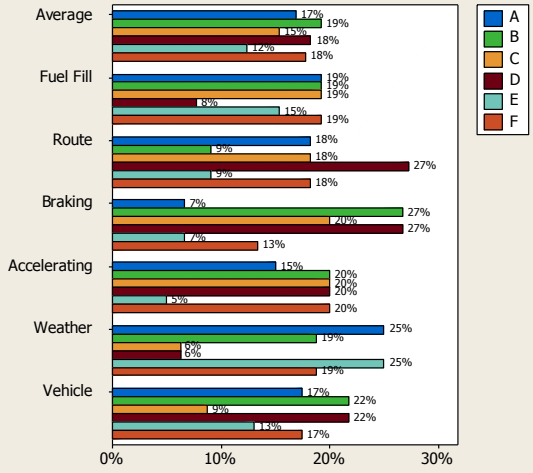
Differences among the outcome percentage profiles are not significant ($p < 0.05$). You cannot conclude there is an association between Person and Factors.

Comments

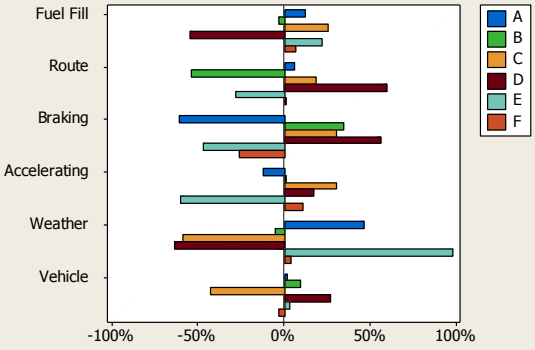
You cannot conclude that there are differences among the outcome percentage profiles at the 0.05 level of significance.

Percentage Profiles Chart

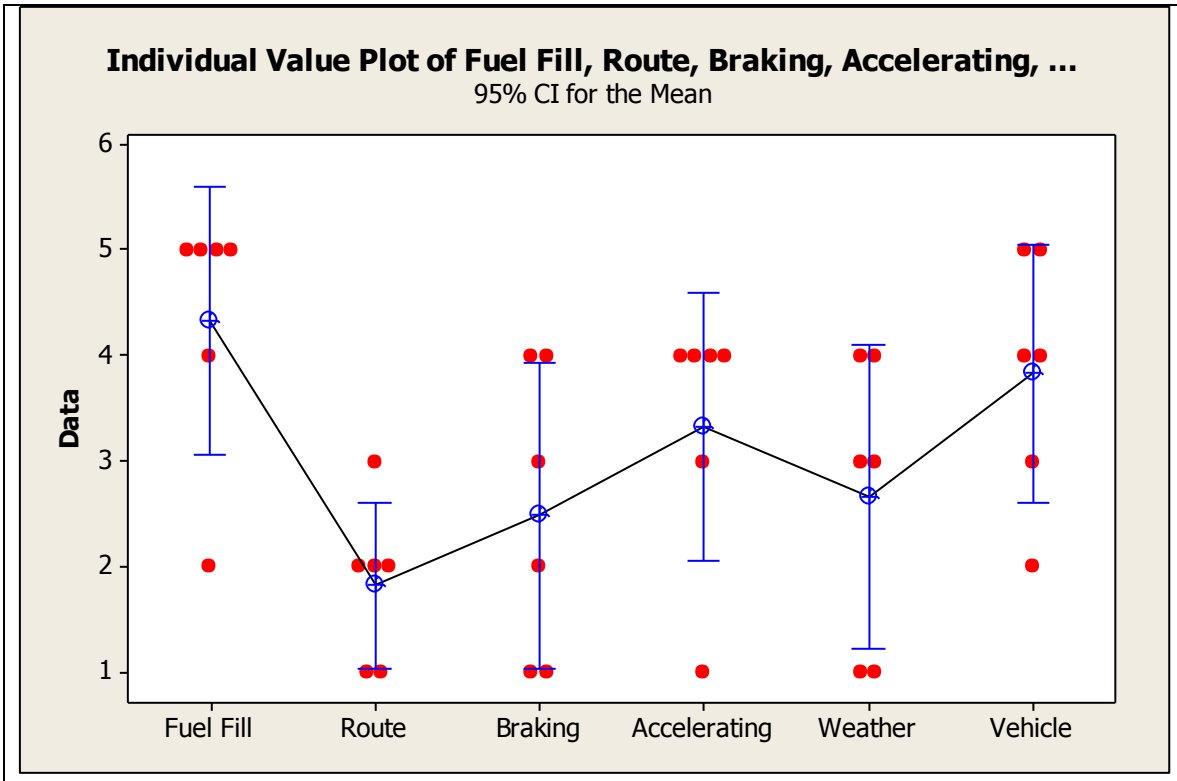
Compare the profiles.

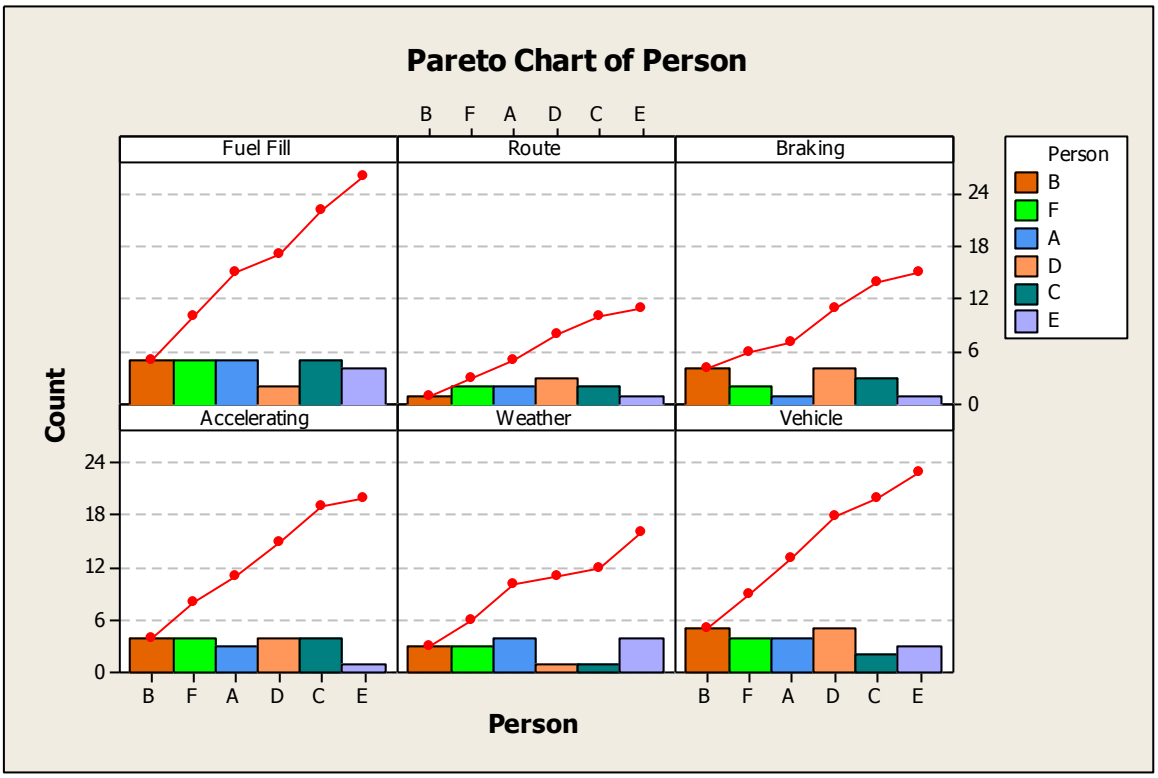


% Difference between Observed and Expected Counts



Positive: Occur more frequently than expected
Negative: Occur less frequently than expected


Individual Value Plot of Fuel Fill, Route, Braking, Accelerating, ...
95% CI for the Mean
Data
6
5
4
3
2
1
Fuel Fill
Route
Braking
Accelerating
Weather
Vehicle


Pareto Chart of Person
B F A D C E
Fuel Fill
Route
Braking
Accelerating
Weather
Vehicle
Count
24
18
12
6
0
Person
B
F
A
D
C
E

I-1. Establish operating tolerances for key inputs and the output. Date: 12/13/11

After examining the grade cards we found that Fuel Fill Technique seemed to be the input with the greatest effect on a FE test failure.

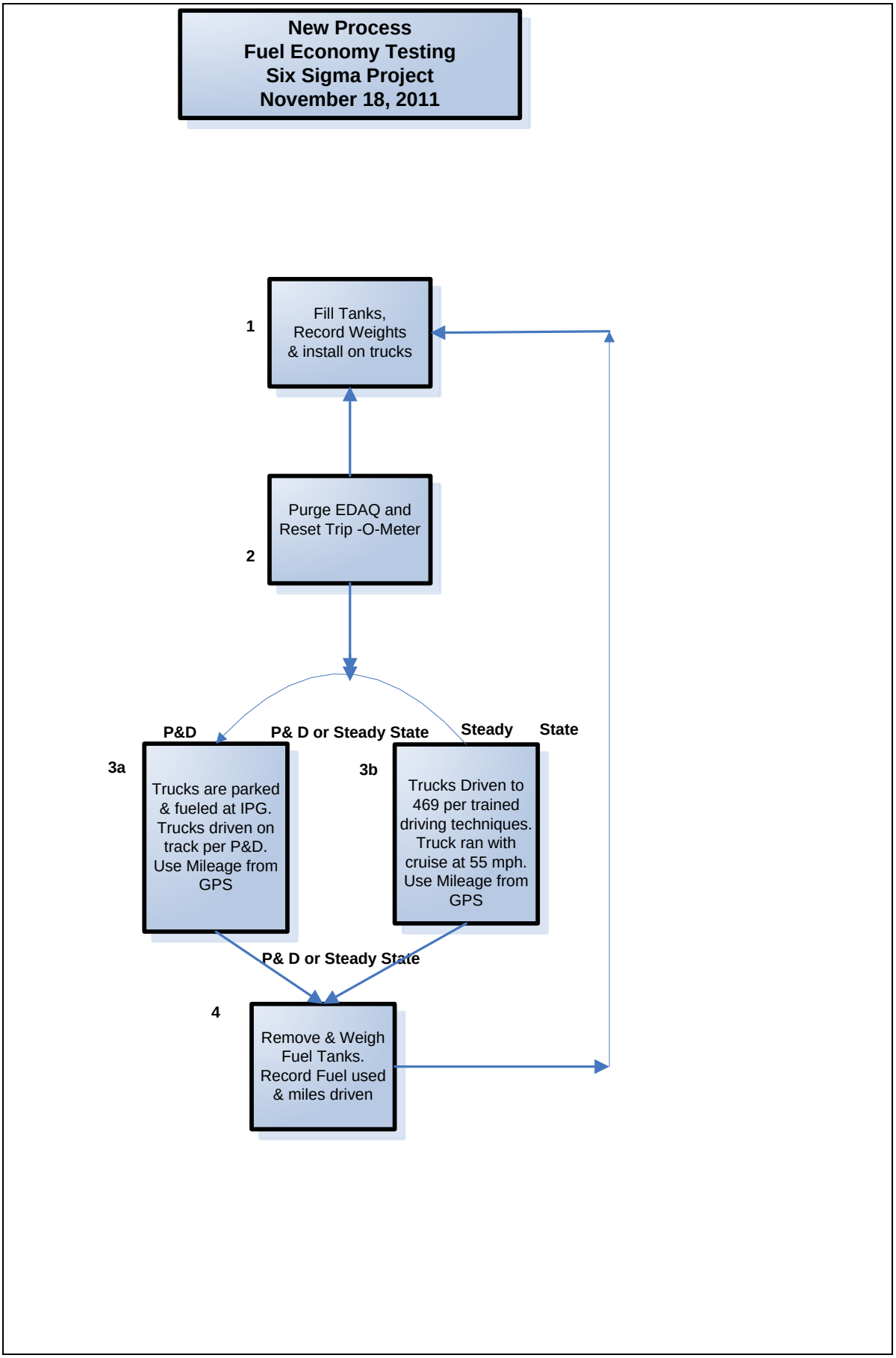
Fuel weight tanks will be used in place of the OEM fuel tanks, Eliminating the Steve Stick & the variation associated with it.

The trucks will be filled & left at the track for P&D testing to eliminate the variance associated with the trip to & from TDTC.

Braking & Acceleration points will be set up on the track to remove a majority of the variation out of the driver's techniques.

Both Vehicles will be serviced & have new batteries installed to make their individual fuel economies more consistent.

In addition to these changes, extra controls will be put into place for the Steady State & P&D Test.


New Process
Fuel Economy Testing
Six Sigma Project
November 18, 2011
1
Fill Tanks, Record Weights & install on trucks
2
Purge EDAQ and Reset Trip -O-Meter
P&D
P& D or Steady State
Steady State
3a
Trucks are parked & fueled at IPG. Trucks driven on track per P&D. Use Mileage from GPS
3b
Trucks Driven to 469 per trained driving techniques. Truck ran with cruise at 55 mph. Use Mileage from GPS
P& D or Steady State
4
Remove & Weigh Fuel Tanks. Record Fuel used & miles driven

I-2. Re-evaluate the measuring system. Date: 12/13/11

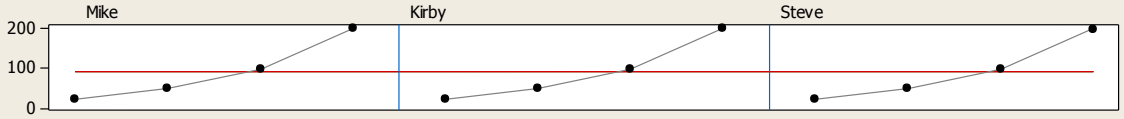
Required tools: Gage R&R/Attribute Agreement Analysis

Run Order	Operators	Parts	Measurements	Run Order	Operators	Parts	Measurements
1	Mike	200	200.1	25	Mike	100	100.1
2	Mike	50	50	26	Mike	200	200.1
3	Mike	100	100.1	27	Mike	50	50
4	Mike	25	25	28	Mike	25	25
5	Kirby	25	25	29	Kirby	25	25
6	Kirby	100	100	30	Kirby	100	100.1
7	Kirby	200	200.1	31	Kirby	50	50
8	Kirby	50	50	32	Kirby	200	200.1
9	Steve	100	100.1	33	Steve	25	25
10	Steve	25	25	34	Steve	100	100
11	Steve	200	200.1	35	Steve	200	200
12	Steve	50	50	36	Steve	50	50
13	Mike	50	50	37	Mike	200	200.1
14	Mike	25	25	38	Mike	25	25
15	Mike	200	200	39	Mike	100	100
16	Mike	100	100.1	40	Mike	50	50
17	Kirby	50	50	41	Kirby	50	50
18	Kirby	200	200.1	42	Kirby	200	200
19	Kirby	25	25	43	Kirby	25	25
20	Kirby	100	100	44	Kirby	100	100
21	Steve	200	200	45	Steve	50	50
22	Steve	50	50	46	Steve	100	100.1
23	Steve	100	100.1	47	Steve	25	25
24	Steve	25	25	48	Steve	200	200

Gage R&R Study for Measurements
Variation Report

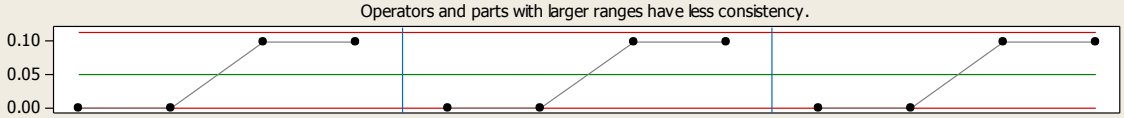
Xbar Chart of Part Averages by Operator

At least 50% should be outside the limits. (actual: 100.0%)



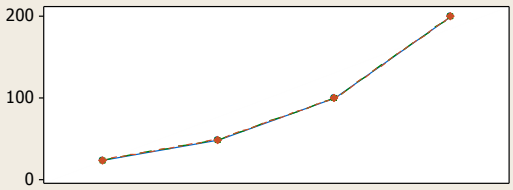
R Chart of Test-Retest Ranges by Operator (Repeatability)

Operators and parts with larger ranges have less consistency.



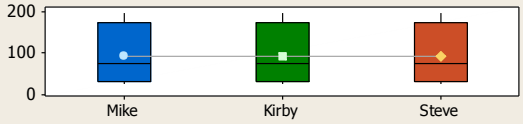
Reproducibility — Operator by Part Interaction

Look for abnormal points or patterns.



Reproducibility — Operator Main Effects

Look for operators with higher or lower averages.



Variation Breakdown

Source	StDev	%Process (data)
Total Gage	0.038	0.05
Repeatability	0.035	0.05
Reproducibility	0.013	0.02
Part-to-Part	77.421	100.00
Process Var (data)	77.421	100.00

Gage R&R Study for Measurements
Summary Report

Can you adequately assess process performance?

0.0% of all process variation can be attributed to the measurement system. The process variation is estimated from the parts in the study.

Study Information

Number of parts in study	4
Number of operators in study	3
Number of replicates	4

(Replicates: Number of times each operator measured each part)

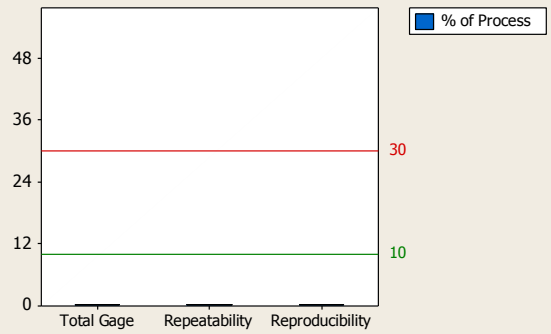
Comments

General rules used to determine the capability of the system:
<10%: acceptable
10% - 30%: marginal
>30%: unacceptable

Examine the bar chart showing the component contributions, and use this information to guide improvements:
-- Test-Retest component (Repeatability): The variation that occurs when the same person measures the same item multiple times. This accounts for 93.7% of the measurement variation. It is 0.0% of the total variation in the process.
-- Operator component (Reproducibility): The variation that occurs when different people measure the same item. This accounts for 34.9% of the measurement variation. It is 0.0% of the total variation in the process.

Variation Breakdown

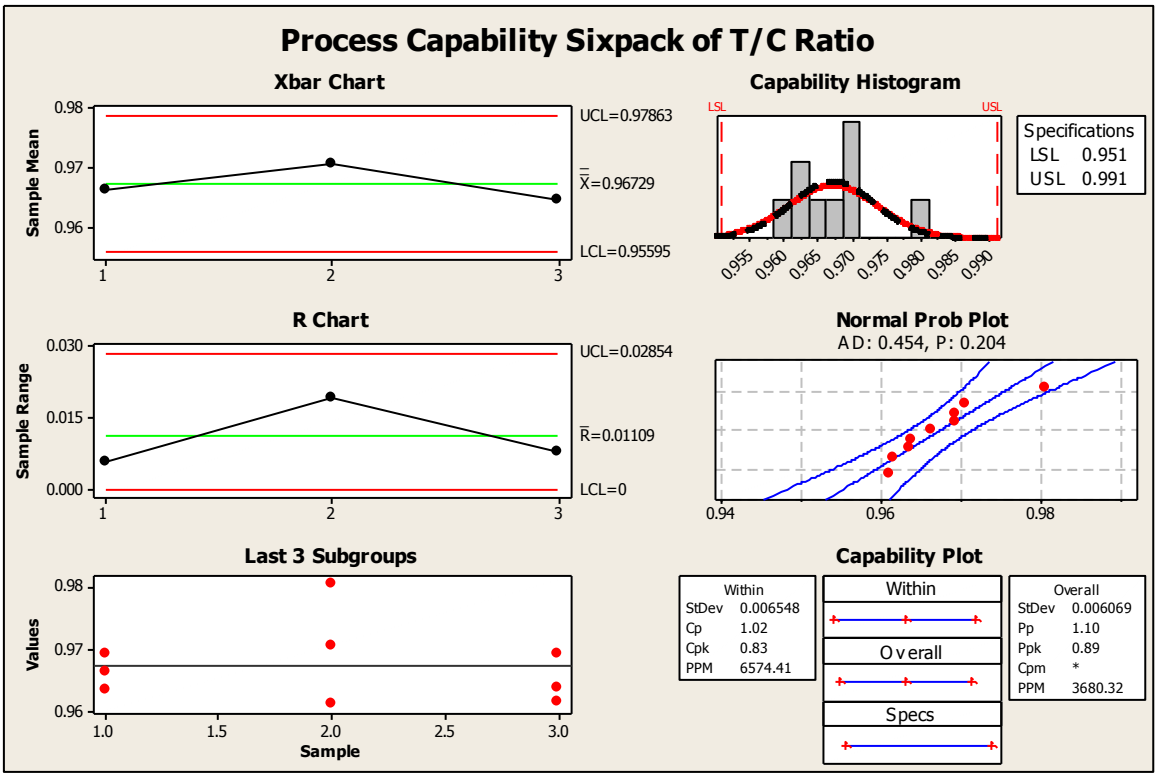
Is there a problem with repeatability or reproducibility?



I-3. Establish final capability for key input(s) and the output. Date: 12/13/11

Required tools: Capability six pack, Control charts

↓	C1	C2-T
	T/C Ratio	Calibration
1	0.966265	Baseline
2	0.963470	Baseline
3	0.969152	Baseline
4	0.970588	Cal 1
5	0.961140	Cal 1
6	0.980583	Cal 1
7	0.961451	Cal 2
8	0.963768	Cal 2
9	0.969194	Cal 2



Final Cp 1.02

C1. Implement process controls for the key inputs. Date:12/13/11

Required tool: Error proofing

List controls including error proofing. Utilize highest level of control possible. Categorize controls 0, 1, 2, or 3.

Drivers ---Driving Habits (Insert controls (Training))
WOT Till- 5 mph of posted speed limits
Coast & Braking same Distance
Cruise set for same time (Steady State SS Only)
Synchronized Lane changes
Level 1 control

Drivers/ Engineer --- (Use satellite mileage)
Miles are set according to course or route.
Too much variation on track when other test is being ran at the same time (using different lanes which vary in length per lap)
Unscheduled but necessary stops on SS route add miles.
Both Speedometers have been Calibrated!
Level 2 control

Truck Maintenance--- (installed new Batteries)
Old methods=
Bad Batteries
Alternators would have to recharge batteries after truck sat. Varied on length of time the truck sat. Extra hp needed = more fuel
New method=
Test to be ran with both trucks running the same accessories through out the entire FE test
Level 1 & 2 control

Follow-up to ensure effectiveness. Date:

No wasted runs as of yet but we've only had 9 runs.

Note: Describe justification(s) for omitting any of the above steps, or required tools.