



Case study on developing 3 cylinder 1.5 Liter cost efficient diesel engine by downsizing with enhanced performance

17-May-2011

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Product Cost Management
Mumbai- India**



Mahindra Group & Products

Product Challenges

Product Features

Cost Management Initiative

Results

Mahindra Group

US\$ 11.5 Billion (FY 2010-11)

Conglomerate with diversified interests

Global excellence at dramatically lower costs

Sustained leadership across the sectors

A very strong corporate brand



EVERY 2 MINUTES A MAHINDRA IS BORN. We call it Rise.

THE ONLY COMPANY HERE TO MAKE EVERYTHING FROM 2-WHEELERS TO TRUCKS.



INTERFACE 18/0008



Moving Force In India's Progress...



**NOT INDIA'S.
NOT ASIA'S.
THE WORLD'S 1ST.**
We call it Rise.

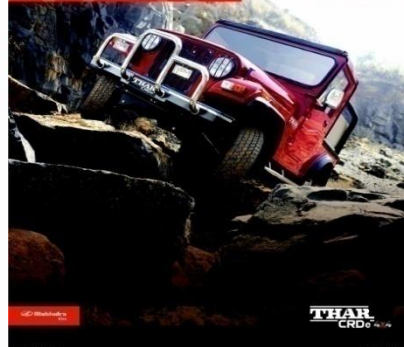
MAHINDRA MAXIMO, THE WORLD'S 1ST 3 CYLINDER 62 CCM POWERED MINI TRUCK.

MAXIMO
THE FORCE OF TRANSFORMITY



**GOING WHERE
EVEN ROADS
REFUSE TO GO.**
We call it Rise.

MAHINDRA THAR ONLY FOR EXTREME 4x4.



THAR
CRUDE

**STYLE
THAT'S STRIKING**

- Stylish van design with hard-top body
- Attractive front grille
- Futuristic clear-lens wraparound headlights
- Modern instrument cluster
- Elegant taillights





MAXIMO
mini van
MAHINDRA MAXIMO 800 (2008-2010)



**WHEN COMING
FIRST BECOMES
SECOND NATURE.**
We call it Rise.

MAHINDRA BOLERO, INDIA'S MOST SELLING SUV IN 2001, 2006, 2009 & 2010.



BOLERO

THE TOWING NEW BOLERO



Mahindra Group & Products

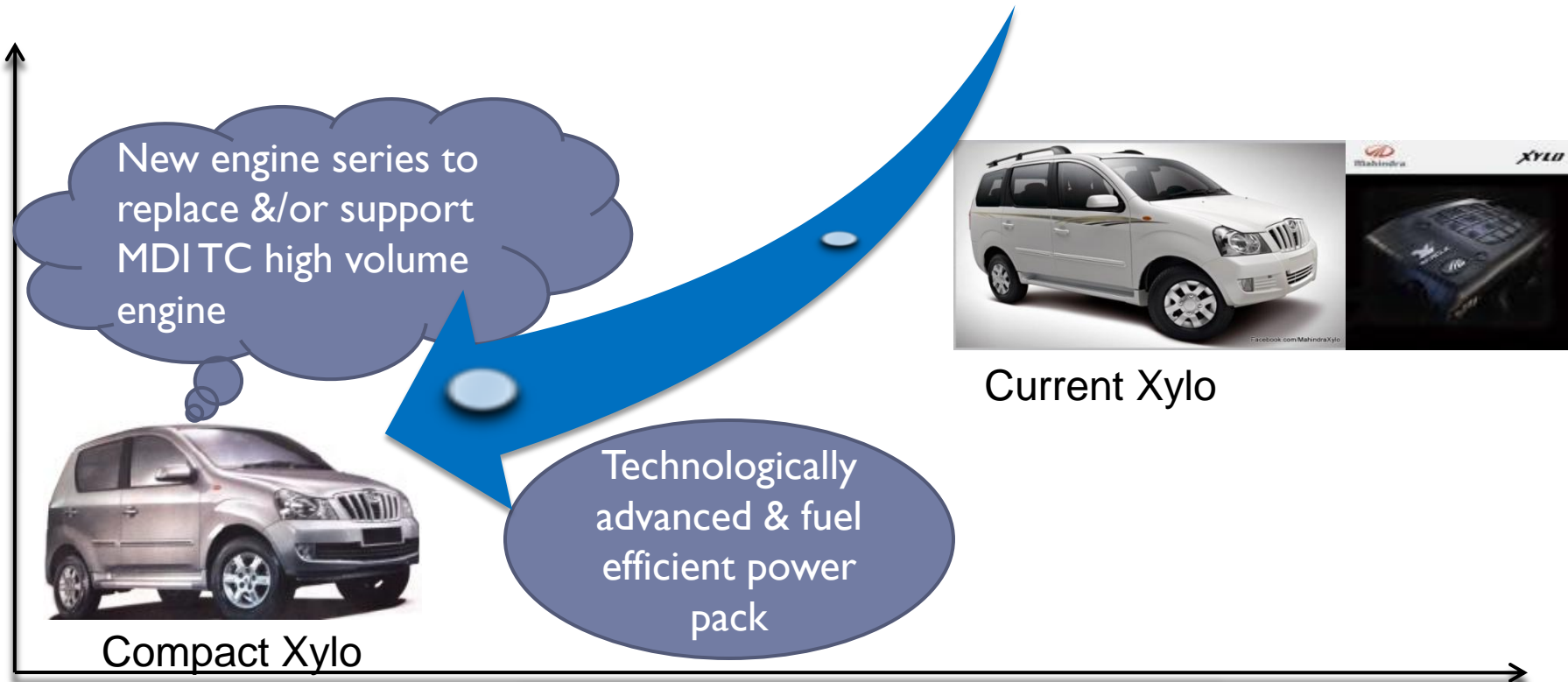
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Strategic Intent



Benchmark Details

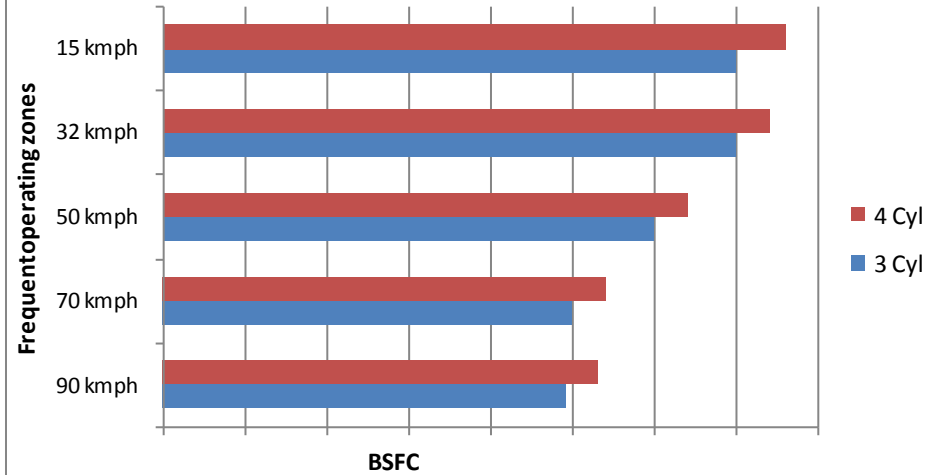
| Description | mEagle (Features Benchmark) | MDICRDe(Design & Cost Benchmark) |
|-------------------------|---|---|
| Bore / Stroke (mm) | 94 mm x 90 mm | 88.9 mm x 100.3 mm |
| Capacity CC | 2498 cc | 2489 cc |
| Max. Power | 79 kW @ 3800 rpm | 69.8 kW @4000 rpm |
| Max. Torque | 240 Nm@1800-2200 rpm | 220 Nm@ 1400-2600 rpm |
| Compression ratio | 17.8 :1 | 18.2 :1 |
| Cylinder arrangement | 4 cylinder-In line | 4 cylinder-In line |
| Type of operation | 4 stroke direct injection, turbocharged, | 4 stroke direct injection, turbocharged, |
| Firing order | 1-3-4-2 | 1-3-4-2 |
| Application | MUV | MUV |
| Min BSFC (gm/KW h) | 215 | 210 |
| High Idle RPM | 4750 | 4200 |
| Low Idle RPM | 850 | 800 |
| Emission Compliant | BS-III, BS-IV | BS-III, BS-IV |
| Dimension (Lx W x H) mm | 728X730X752 | 690.2 x 662.6 x 794.7 |
| Dry Weight kg | 295 | 250 |

Proposed Engine Specification

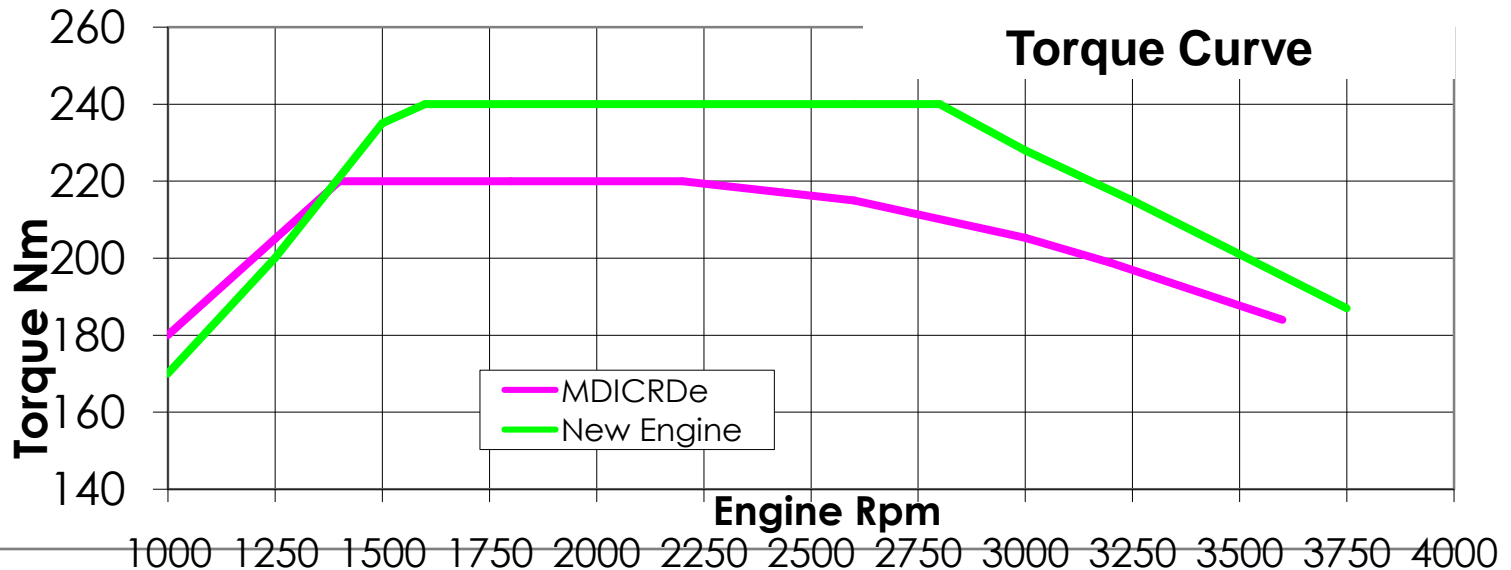
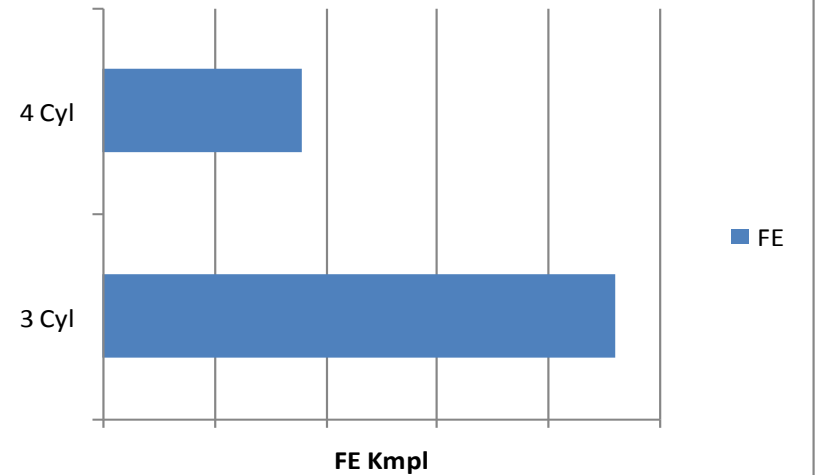
| Description | MDICRDe | New Engine | Differentiation of New engine |
|-------------------------|--|---|-------------------------------------|
| Bore / Stroke (mm) | 88.9 mm x 100.3 mm | 83 mm x 92 mm | <i>Compact Engine</i> |
| Capacity CC | 2489 cc | 1493 cc | <i>Capacity 996cc less</i> |
| Max. Power | 69.8 kW @4000 rpm | 73.5 kW @ 3750 RPM | 4Kw better than MDICRDe |
| Max. Torque | 220 Nm@ 1400-2600 rpm | 240 Nm@ 1600-2800 rpm | Best in Class low end torque |
| Compression ratio | 18.2 :1 | 18.5 :1 | |
| Cylinder arrangement | 4 cylinder-In line | 3 cylinder-In line | |
| Type of operation | 4 stroke direct injection, turbocharged, | 4 stroke direct injection, twin turbocharged, | <i>Advanced turbocharging,</i> |
| Firing order | 1-3-4-2 | 1-2-3 | |
| Application | MUV | MUV | |
| Min BSFC (gm/KW h) | 210 | 215 | <i>Best in Class fuel Economy</i> |
| High Idle RPM | 4200 | 4750 | |
| Low Idle RPM | 800 | 900 | |
| Emission Compliant | BS-III, BS-IV | BS IV, BS-V | |
| Dimension (Lx W x H) mm | 690.2 x 662.6 x 794.7 | 493X660X790 | <i>Shortest engine</i> |
| Dry Weight kg | 250 | 185 | Lightest Engine |

Downsizing Advantages

BSFC Improvement



Fuel Efficiency



Note
 4 Cyl- MDICRDe engine
 3 Cyl- New 1.5 ltr Engine



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Product Challenges

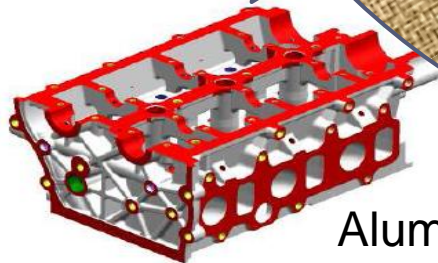
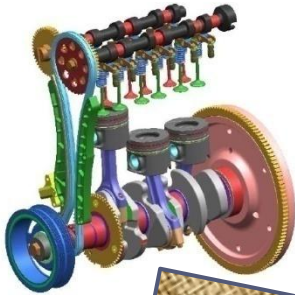
Product Features

Cost Management Initiative

Results

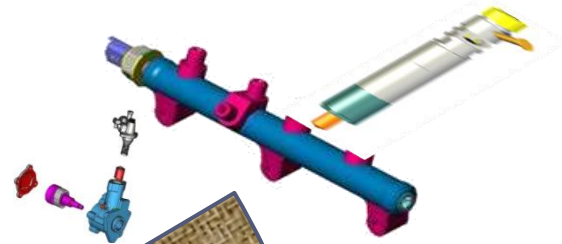
Product Feature- Challenges

Advanced Crank train
& Valve System



Aluminum Head
with DOHC

TECHNOLOGY



Common Rail



Advanced Turbo
charging



Integral Front cover with Oil
Pump & Water Pump

Product Feature- Comparison

| Components | New Engine | Benchmark Engine |
|---------------|---|------------------------------|
| Fuel System | Low Cost Common Rail with Unit Pump+ Cam Box Assembly | CRDe |
| Piston | Gallery Cooled | Non Gallery Cooled |
| Cam Shaft | DOHC | SOHC |
| Cylinder Head | Aluminium | Cast Iron |
| Valve Train | 4 Valve per Cylinder | 2 Valve per Cylinder |
| | RFF,HLA | Conventional Rocker assembly |
| Oil Sump | Aluminium | Sheet Metal |
| Drive Type | Chain | Gear |
| Alternator | Alternator + Stand alone Vacuum Pump | Alternator with Vacuum Pump |
| Emission | BS III, IV & V (protection) | BS III & BS IV |



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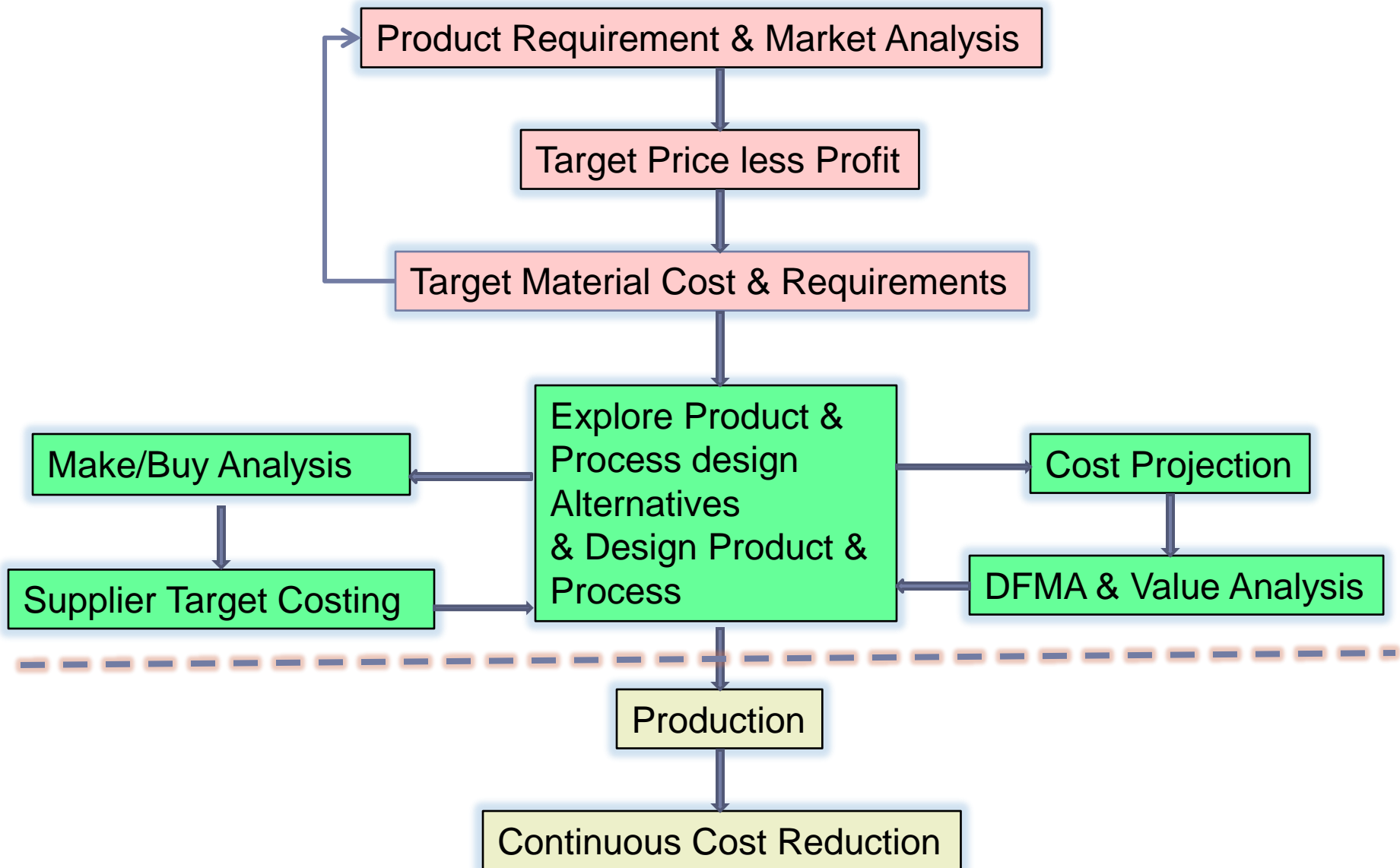
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Target Cost Concept



Upstream Costing Tools

ANALOGIC

- ✓ option List
- ✓ carry-over
- ✓ rough Cost assesment

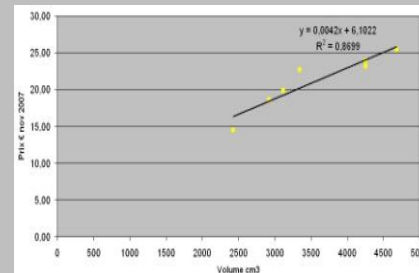
Ø Elliptic module :

60 66 70 80

Guess-
estimation

PARAMETRIC

- ✓ Need data correlations « $y = ax + b$ »
- ✓ Suited for relatively standard designs



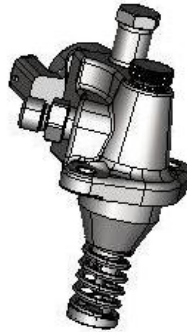
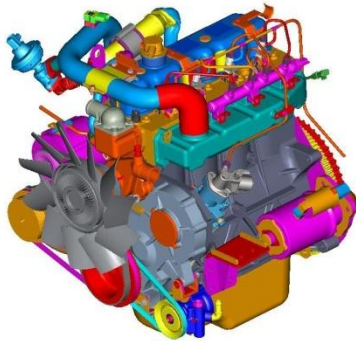
Estimation

ANALYTIC

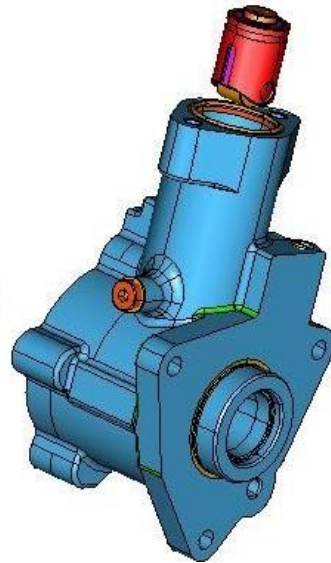
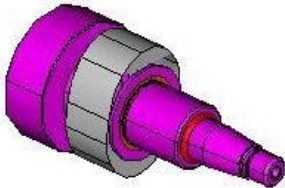
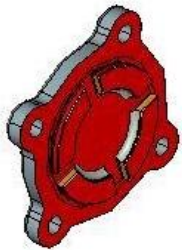
- ✓ no relevant corrélation or too much time consuming compare to accuracy

Should be
Costing &
Black Box
Costing

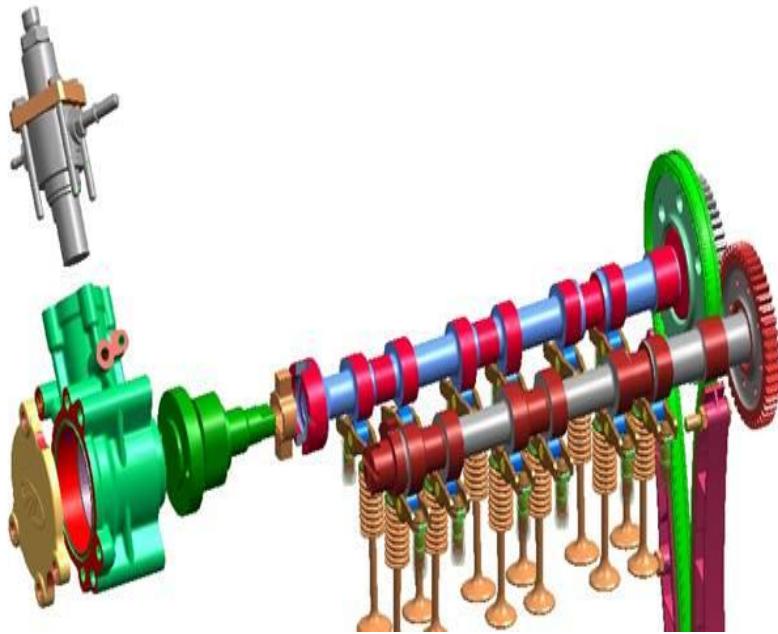
Upstream Costing Tools- Analogic



- Low Cost Common Rail (LCCR) System from M/s. BOSCH
- Development of Common Rail using traditional PF Pump
- Use of Inlet metering to have better FE and Performance.
- Cam Box Design Patented under M&M Flagship



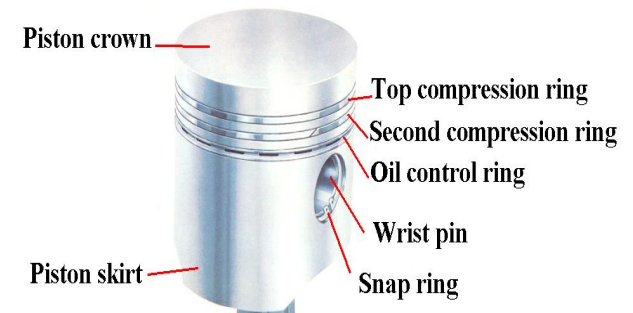
Upstream Costing Tools- Analogic



- PF pump for 4 & 3 Cylinder engine. First time in India.
- Learning from other LCCR 4 Cylinder engine captured to reduce the cost & ease of manufacturing.
- Cast oil gallery instead of machining resulted in cost saving.

Upstream Costing Tools- Parametric

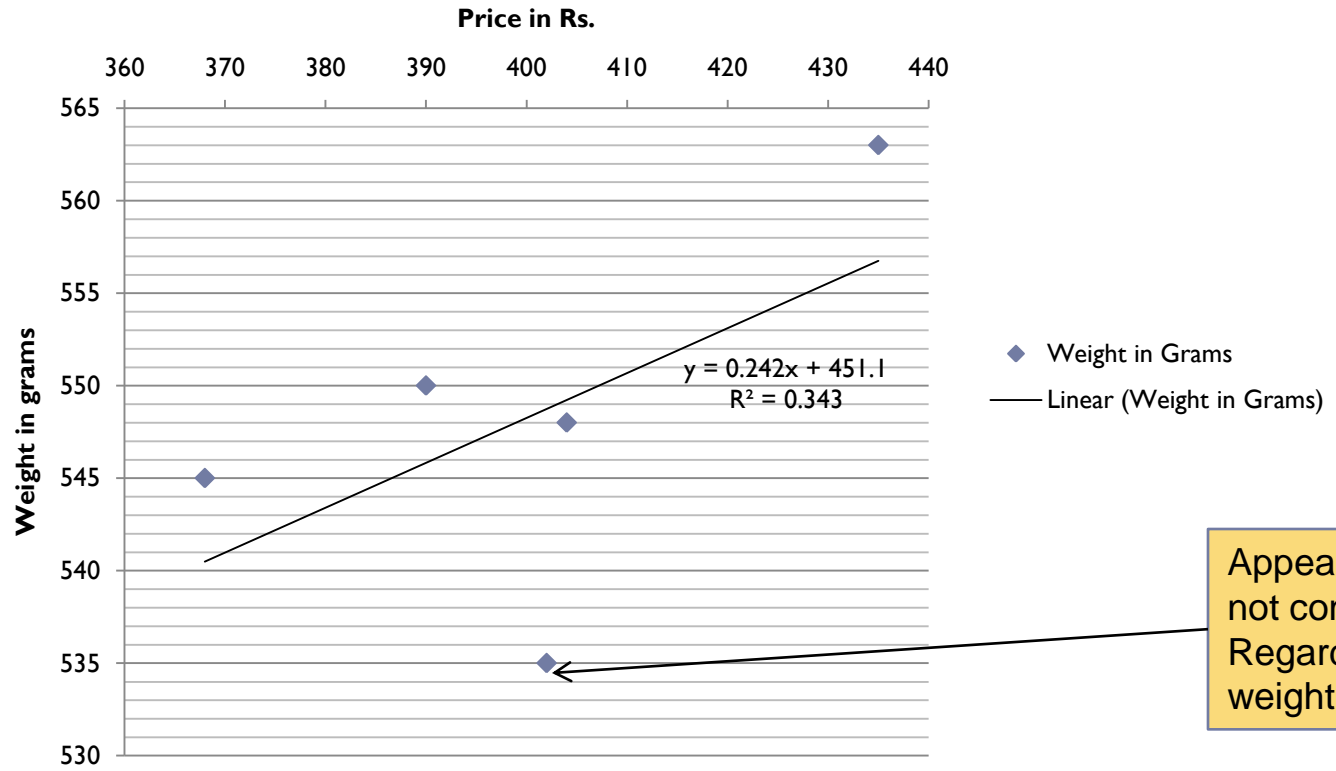
| Sr.No. | Piston Paramater | Maxximo | Bolero- DI | Genio | mEagle | Mhawk | Gio |
|--------|---------------------------------|---------|------------|--------|--------|--------|--------|
| 1 | Total production volume (parts) | 200000 | 680000 | 144000 | 120000 | 160000 | 80000 |
| 2 | Engine type (Gasoline / Diesel) | Diesel | Diesel | Diesel | Diesel | Diesel | Diesel |
| 3 | Diameter in MM | 83 | 88.9 | 88.9 | 93.9 | 85 | 84.9 |
| 4 | Stroke Length (Total Height) | 67.75 | 84.35 | 75 | 90.08 | 73 | 73 |
| 5 | Net Weight | 535 | 545 | 563 | 548 | 603 | 580 |
| | DESIGN | | | | | | |
| 6 | Ring Insert (Yes / No) | Yes | Yes | Yes | Yes | Yes | Yes |
| 7 | Gallery (Yes / No) | No | No | No | No | No | Yes |
| | SURFACING TREATMENT | | | | | | |
| 8 | Graphite coating (Yes / No) | No | Yes | No | Yes | Yes | Yes |
| 9 | Phosphate coating (Yes / No) | No | No | No | Yes | Yes | Yes |
| 10 | Moly Coating (yes/No) | Yes | No | Yes | No | No | No |



Design Concept Sheet data for Piston

Piston Search for Correlation

Piston weight Vs Price



Upstream Costing Tools- Analytic (SBC)

Process

- Ideal Process

Variable cost

- Direct material / Direct Labor
- Power and Fuel
- Consumable Tools, Indirect material
- Packaging & Logistics

Fixed cost

- Plant & Machinery, Depreciation
- Capital Tool (Patterns, Dies, Jigs & Fixtures)
- Salaries & Overheads

Balance Sheet of suppliers

- Financial Ratios for cost structure

* SBC:- Should Be Costing

Upstream Costing Tools- Analytic (SBC)

| Part Number | Factor | Cost in Rs. |
|-----------------------------|--------|---------------|
| Description | | Crank Gear |
| Material Grade | | 20MnCr5 |
| GIPW | | 0.87 |
| Forging Wt in kg. | | 0.73 |
| Finish Weight in kg | | 0.30 |
| Scrap wt | | 0.15 |
| RM Rate in Rs. | 40.67 | 35.42 |
| Scrap Rate | -13.00 | -1.89 |
| Material Cost | | 33.54 |
| | | |
| Forging Rs/Kg | 12 | 10.45 |
| Normalizing Rs/Kg | 4 | 2.90 |
| Forging Cost Rs/Pc | | 13.36 |
| Forging + RM | | 46.89 |
| ICC OH Profit | 5% | 49.24 |
| Inspection | | 2.50 |
| Landed Forging Price | | 51.74 |
| Machining | | 73.26 |
| Assy Cost incl HT | | 35.80 |
| Process Cost | | 109.06 |
| Scrap Recovery | -13 | -5.54 |
| Sub Total | | 155.26 |
| Rejection | 2% | 3.11 |
| OH | 7.5% | 8.18 |
| Returnable Packing | | 0.50 |
| Profit | 8% | 8.72 |
| Final Price in Rs. | | 175.77 |



Upstream Costing Tools- Black Box Costing

1. Costing Hypothesis

2. Part Price details

3. D&D Details

4. Cost Synthesis

5. Data Comparison With Supplier

6. Use of Push –Pull & Techno-economical methodology to bridge the gap

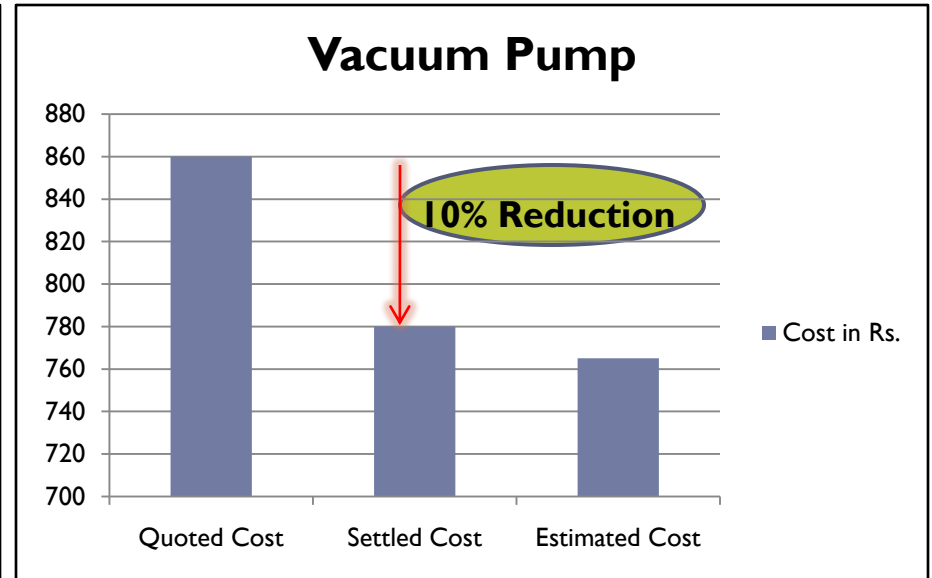
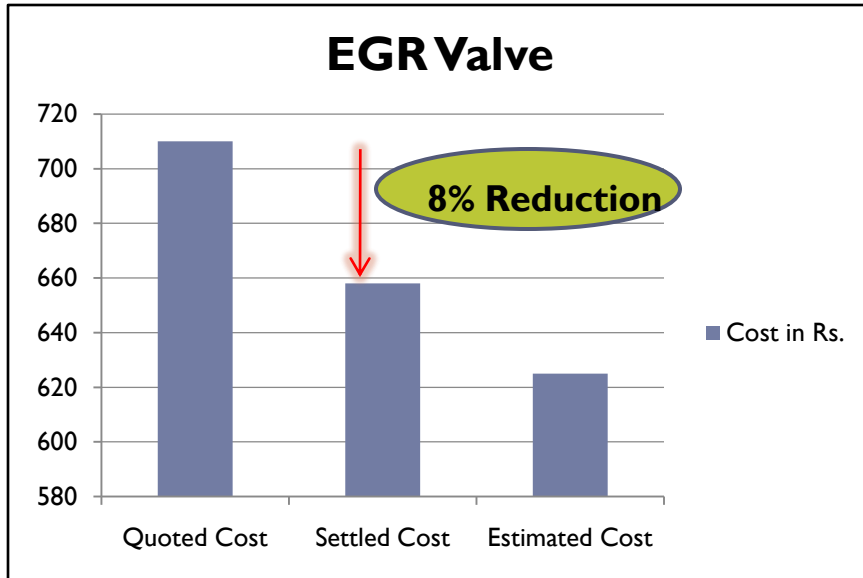


Black Box Costing Example- EGR Valve

| Remark | Weight in Grams | Inhouse/OS | Ref Drg. | Raw mat price (INR) | Raw Material | Injection | Casting | Stamping | Machining | Welding | Cleaning | Checking | Other (assembly) | Painting | Total / unit | Total / part | Quote Padmini | Quote P. + OH + Profit + Finance |
|-------------------|-----------------|------------|--|---------------------|--------------|-----------|-----------|----------|-----------|-----------|----------|----------|------------------|----------|--------------|--------------|---------------|----------------------------------|
| | 331.5 | Inhouse | | 64 | 23,34 INR | | 10,45 INR | | 25,95 INR | 1,33 INR | | 0,70 INR | | 1,00 INR | 61,77 INR | 61,77 INR | 75,96 INR | 95,59 INR |
| ZN. Plated Yellow | | Outsourced | Ring welded at bottom side of Cap (Bottom) | | 1,50 INR | | | | | 2,00 INR | | | | | 3,50 INR | 7,00 INR | | |
| ZN. Plated Yellow | 100 | Outsourced | | 35 | 4,52 INR | | | 3,87 INR | | | | | 1,00 INR | | 9,39 INR | 18,79 INR | 12,34 INR | 15,53 INR |
| | 24 | Outsourced | | 179 | 4,30 INR | | | | | 12,11 INR | | | | | 16,41 INR | 16,41 INR | 14,24 INR | 17,92 INR |
| ZN. Plated Green | 62,05 | Outsourced | | 35 | 2,73 INR | | | 5,63 INR | | 0,50 INR | | | | 1,00 INR | 9,86 INR | 9,86 INR | 12,67 INR | 15,94 INR |
| ZN. Plated Green | 81,09 | Outsourced | | 35 | 3,57 INR | | | 2,76 INR | | | | | | | 6,33 INR | 6,33 INR | 6,45 INR | 8,12 INR |
| Imported | 3,5 | Imported | | | 1,28 INR | | | | | | 4,60 INR | | | | 5,88 INR | 5,88 INR | | |
| | 39 | Outsourced | | 352 | 34,32 INR | | | | 18,63 INR | | | | | 1,00 INR | 53,95 INR | 53,95 INR | 46,21 INR | 58,15 INR |
| | 30 | Outsourced | | 35 | 2,11 INR | | | | 18,47 INR | | | | | | 20,58 INR | 20,58 INR | 7,80 INR | 9,82 INR |
| | 27 | Outsourced | | 35 | 1,58 INR | | | | 22,29 INR | 10,00 INR | | | | | 33,87 INR | 33,87 INR | 48,55 INR | 61,10 INR |
| | 39 | Outsourced | | 35 | 1,72 INR | | | | 4,99 INR | | | | | | 6,71 INR | 6,71 INR | | |
| | | Outsourced | | | 1,07 INR | | | | | | | | | | 1,07 INR | 3,20 INR | | |
| | 5 | Outsourced | | 35 | 0,35 INR | | | | | | | | | | 2,15 INR | 2,15 INR | | |
| | 10 | Outsourced | | 205 | 4,10 INR | | 1,00 INR | 0,05 INR | | | | | | | 5,15 INR | 5,15 INR | | |
| Zn. Plated | 5 | Outsourced | Part is Brazed in Cap (Top) | 35 | 0,22 INR | | | | | | | | | | 5,22 INR | 5,22 INR | | |
| Non Asbestos | 10 | Outsourced | Green Gasket visible on Cap (Bottom) | 205 | 2,28 INR | | | | | | | | | | 2,28 INR | 2,28 INR | | |
| ZN Plated Yellow | 30 | Outsourced | | 35 | 1,32 INR | | | | | | | | | | 4,08 INR | 4,08 INR | | |
| ZN Plated Yellow | 5 | Outsourced | | 35 | 0,22 INR | | | | 2,19 INR | | | | | | 2,41 INR | 2,41 INR | | |
| Non Asbestos | 30 | Outsourced | Black Gasket is visible on Cup Washer (Medium) | 205 | 6,83 INR | | 2,00 INR | 1,00 INR | | | | | | | 9,83 INR | 19,65 INR | | |
| Black | 10 | Outsourced | Part is visible on Bush | | 1,00 INR | | 1,00 INR | 0,05 INR | | | | | | | 2,05 INR | 2,05 INR | | |
| Black | 0,2 | Outsourced | | 35 | 0,35 INR | | | | 2,43 INR | | | | | | | | | |
| | 6 | Outsourced | | 205 | 0,08 INR | | | | 0,13 INR | | | | | | | | | |
| | 4 | Outsourced | | 35 | 0,21 INR | | | | 2,39 INR | | | | | | | | | |
| ZN Plated Blue | 3 | Outsourced | | 35 | 0,14 INR | | | | 0,13 INR | | | | | | | | | |
| | 3 | Outsourced | | 35 | 0,04 INR | | | | 0,13 INR | | | | 0,89 INR | | 442,23 INR | 442,23 INR | 454,65 INR | 95,59 INR |
| | 3 | Outsourced | | 35 | 0,04 INR | | | | 0,13 INR | | | | | | | | | |
| | 10 | Outsourced | | 35 | 0,44 INR | | | | 2,00 INR | | | | | | 2,44 INR | 2,44 INR | | |
| | | Outsourced | | | 0,21 INR | | | | | | | | | | 0,21 INR | 0,64 INR | | |
| | 5 | Outsourced | | 35 | 0,22 INR | | | | 2,19 INR | | | | | | 2,41 INR | 2,41 INR | | |
| | 10 | | | 198 | 2,09 INR | 1,00 INR | | | | | | | | | 3,09 INR | 3,09 INR | | |
| | | | | 384 | 1,92 INR | 1,00 INR | | | | | | | | | 2,92 INR | 2,92 INR | | |
| | | | | | | | | | | | | | | | 18,69 INR | 18,69 INR | 38,00 INR | 47,82 INR |

Cost breakdown 31 parts

Results- Black Box Costing



Structured Analysis leads to cost saving



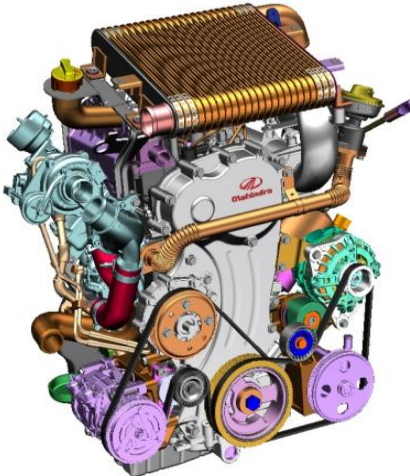
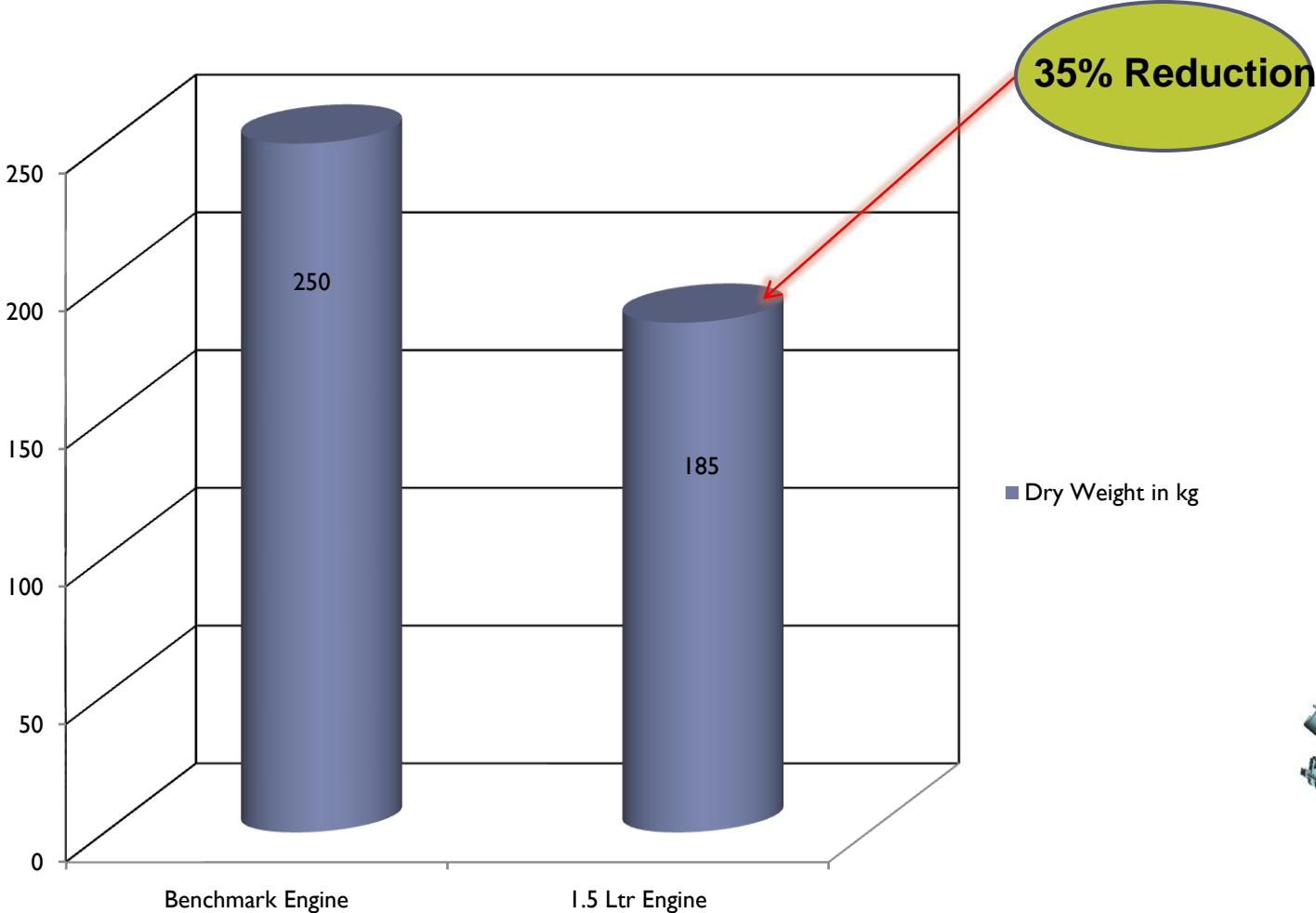
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Results - Downsizing

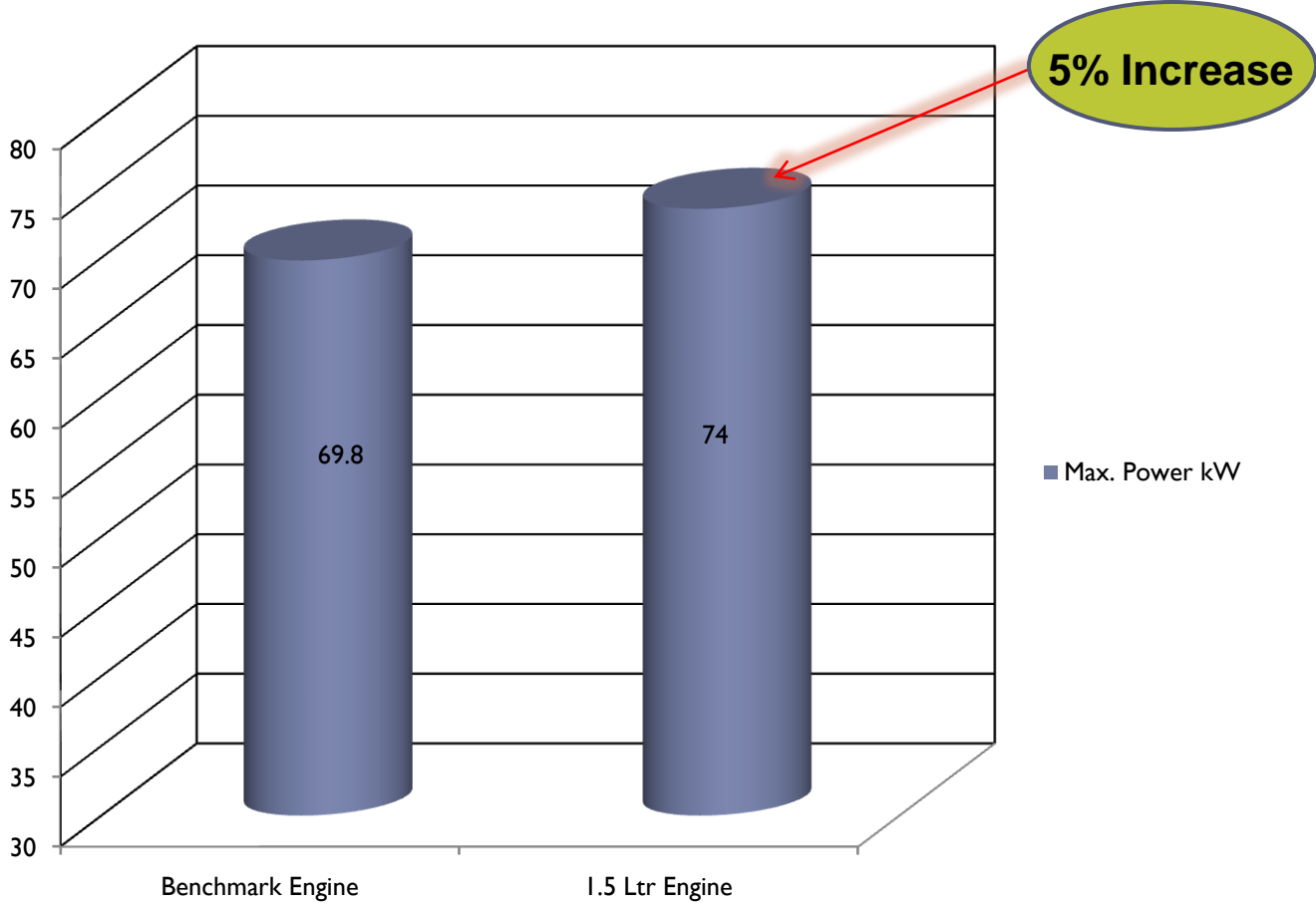
| Part Name | Weight Benefits | Remark |
|----------------|-----------------|--|
| Cylinder Head | 60% | Material Change from CI to Aluminium |
| Crank Case | 40% | 4 Cylinder Vs 3 Cylinder |
| Crank Shaft | 44% | 4 to 3 Cylinder |
| Front Cover | 30% | Aluminium cover integral with water & oil Pump |
| Connecting Rod | 26% | Fractured Con Rod Vs Split Con Rod |
| Cam Cover | -115% | Sheet metal to Aluminium |
| Oil Sump | -45% | Material Change from CI to Aluminium |
| Cam Shaft | -2% | DOHC Vs SOHC |

Right drivers for weight reduction

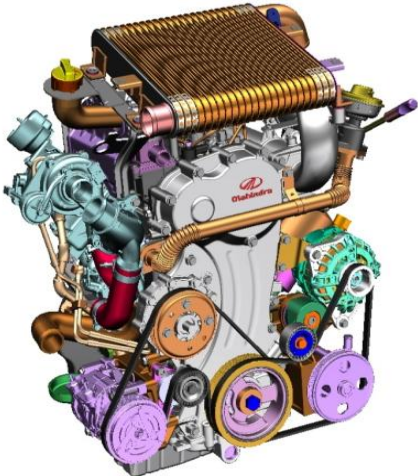
Results - Downsizing



Results – Increased Power

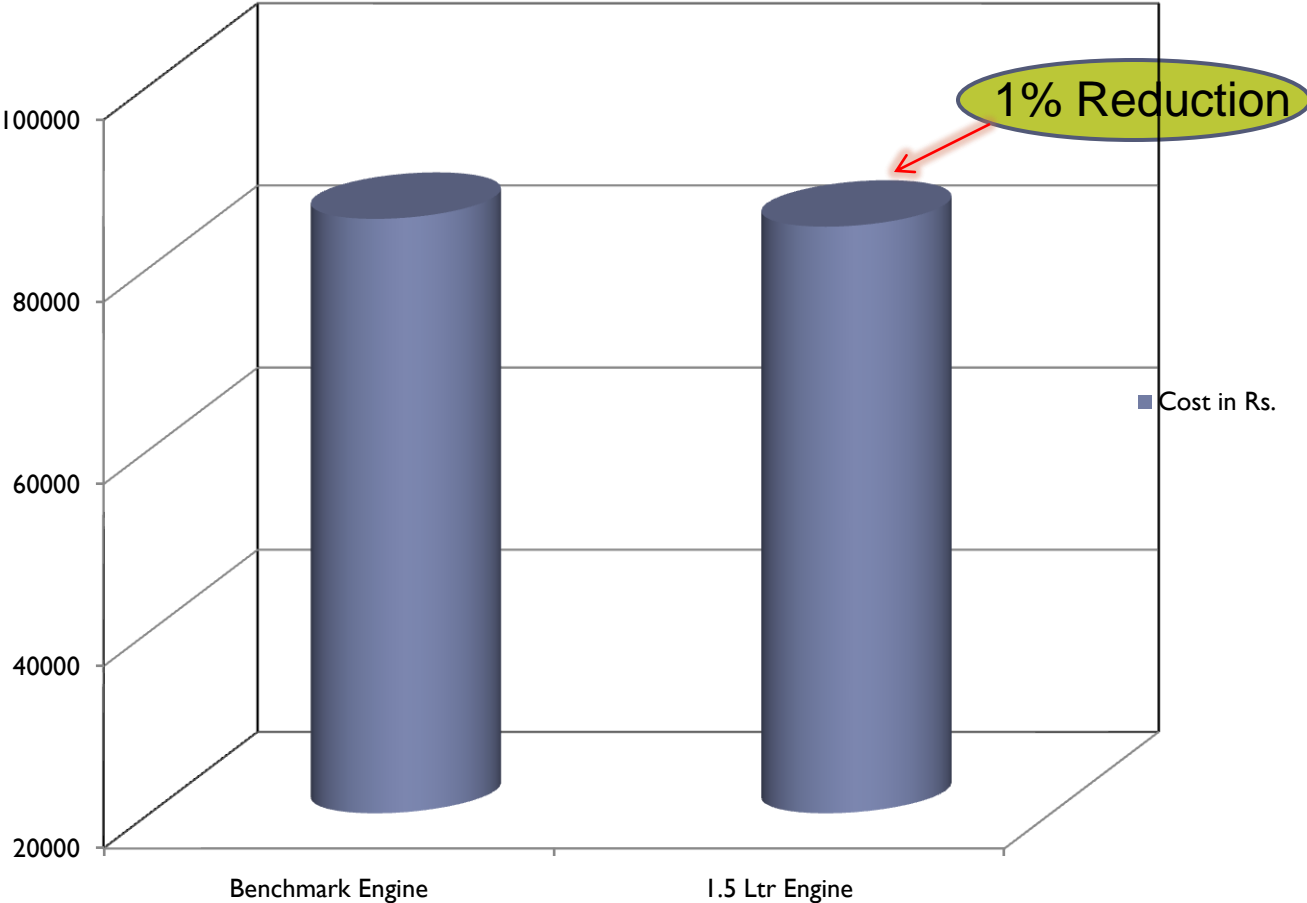


Enhanced Performance

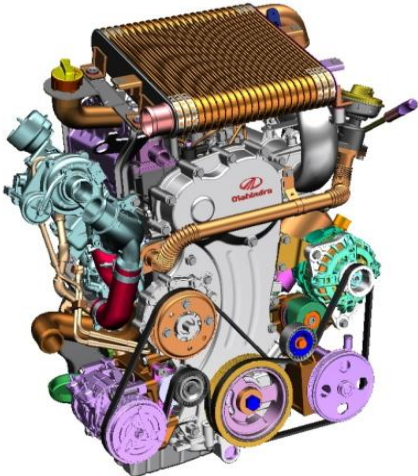


Results – Cost Reduction

Engine Cost Comparison



Downsizing with Cost Reduction



Summary

Development of 1.5 Ltr- 3 Cylinder Diesel Engine

Major Features

- DOHC,
- Bosch LCCR System,
- Integrated front cover (water-oil pump),
- EGR module & advanced turbocharger etc.

Manufacturing strategy

- Head/Block finish machining and engine assembly In-house,
- Balance parts outsourced locally.

Cost Management Approach

- Analogical, Analytical & Parametric costing

Results (In comparison with Benchmark Engine)

- 35% weight reduction
- 9% Torque Increase
- 5% Power Increase,
- 2% Improvement in Fuel Economy
- 1% cost reduction

THANK YOU



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