

The Big Data Application Strategy for Cost Reduction in Automotive Industry

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ABSTRACT

Cost reduction in the automotive industry becomes a widely-adopted operational strategy not only for Original Equipment Manufacturers (OEMs) that take cost leader generic corporation strategy, but also for many OEMs that take differentiation generic corporation strategy. Since differentiation generic strategy requires an organization to provide a product or service above the industry average level, a premium is typically included in the tag price for those products or services. Cost reduction measures could increase risks for the organizations that pursue differentiation strategy.

Although manufacturers in the automotive industry dramatically improved production efficiency in past ten years, they are still facing the pressure of cost control. The big challenge in cost control for automakers and suppliers is increasing prices of raw materials, energy and labor costs. These costs create constraints for the traditional economic expansion model. Lean manufacturing and other traditional 6 Sigma processes have been widely utilized to reduce waste and improve efficiency in the automotive industry. However, these processes and measures are still a reactive strategy and will not provide break-through impacts on automotive OEMs.

It is very challenging for an organization that pursues differentiation generic strategy to drive down cost without affecting its premium pricing strategy. Big Data technologies, which have evolved rapidly in past ten years in the Information Technology (IT) industry, show promise in linking aggregated real-time customers' application pattern to the product design and manufacturing phase. The Big Data technologies enable automotive OEMs to pursue innovative measures to drive down costs.

When Big Data technologies are used according to typical reactive strategies in cost reduction, they do not bring revolutionary improvement for cost control as well. The ultimate power of Big Data technologies relies on the implementation of new strategies. Real-time data analytics for the adaptive calibration and circular-economy development are given in this paper as Big Data application strategy in the automotive industry.

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INTRODUCTION

In traditional corporation strategies theory [1], a market winner has to pursue one of the three strategies to keep the leadership position in a market. These strategies are cost leader, differentiation and focus strategy. Focus strategy is especially suitable to niche markets, where Original Equipment Manufacturers (OEMs) can provide fast responses to the market trend and clients' special requirements. OEMs can provide customized solutions in niche markets to retain the clients. When an OEM takes differentiation strategy, it typically

will be a price leader as well, since there is always premium coded in the market price to compensate for the cost associated with high quality or market image.

During the globalization process, price competition becomes more intense for automotive markets around the world. More and more OEMs adopt lean manufacturing methodologies, and cost reduction becomes a wide topic for all market players. Not only do OEMs that take cost leader strategy actively push down cost, but also every global OEM likes to utilize economic scale to cut cost.

On the other side, price of raw materials, energy and labor costs are under increasing pressure. The impact on automotive OEMs and suppliers is dramatic, and the increase of cost can easily eat manufacturers' profits.

Many measures have been adopted by automotive OEMs to cope with cost reduction, such as lean manufacturing, instant inventory system, utilizing "market pull" to lead manufacturing and Toyota Production System. The core concept behind these methodologies is to chase waste during manufacturing and minimize the waste.

There are also risks associated with these cost reduction measures. For example, extreme simplification and downsizing of certain components could minimize robustness of a system. Robustness in many cases has a positive relationship with quality and customers' delights. Instant inventory management can reduce supply chain cost, but minimum inventory can also lead to assembly shutdown when natural disaster disturbs the prefixed step of lead time.

Table 1. Big Data Application For the Manufacturing Sector

Impacted Manufacturing Value Chain	Potential Benefits From Big Data Application
Research, Development and Design	Build consistent interoperable, cross-functional R&D and product design database to enable concurrent engineering, rapid experimentation and co-creation
Research, Development and Design; Marketing and Sales	Aggregate customer data and make them widely available to improve service level; capture selling opportunities
Research, Development and Design; Marketing and Sales	Source and share data through virtual collaboration sites
Supply-Chain; Production; Marketing and Sales	Implement advanced demand forecasting and supply planning
Production	Implement sensor data-driven operations analytics to improve throughput and enable mass customization
Production	Implement lean manufacturing and model production virtually
Production; Marketing and Sales; After-Sales Service	Collect after-sales data from sensors and feed back in real time to trigger after-sales services and detect manufacturing or design flaws

Chasing waste actually follows a reactive pattern in cost reduction. OEMs first need to pinpoint where waste is by monitoring a variety of performance indicators. The second step is to analyze and mitigate the waste to reduce cost.

Big Data paradigm has been widely discussed in the Information Technology (IT) industry. Many techniques and technologies have been developed recently to meet industrial needs. The utilization of Big Data technologies can proactively reduce cost in the automotive industry.

A research report from McKinsey Global Institute [2] has summarized the potential benefits of Big Data technologies for the manufacturing sector. Table 1 describes these benefits.

Some benefits listed above can be also achieved by other traditional methodologies that are widely used in the automotive engineering domain. One of the most used Continuous Product Improvement (CPI) methodologies is DMAIC, an acronym for the following five phases of the 6 Sigma process: Define, Measure, Analyze, Improve and Control. Following the 6 Sigma process, an OEM can effectively improve product performance and reduce warranty cost. In most cases, the cost in manufacturing can also be reduced when 6 Sigma standards are set for the subsystems and components. Table 2 describes the steps of a typical DMAIC process.

Table 2. 6 Sigma - DMAIC

6 Sigma Phase	Description
Define	Define opportunities: machine performance improvement, operation cost, engine noise, and powertrain maintenance
Measure	Machine response, engine cylinder pressure, oil life and turbocharger speed
Analyze	Given Voice of the Customer, system engineers, component engineers, and calibration engineers integrate all subsystems' requirements to locate optional solutions
Improve	Optimize optional solutions to find a best one
Control	Safety margins control, service engineer feedbacks

When Big Data technologies are used as tools for the 6 Sigma process, they do not bring revolutionary improvement for cost control. Big Data technologies might work more efficiently in aggregating data to support high-level decisions. The ultimate power of Big Data technologies relies on the implementation of new strategies.

There are two domains in which Big Data application can dramatically drive down total cost for automotive OEMs and suppliers:

1. Instead of reactively driving down cost, Big Data technologies can proactively minimize cost. The key is to link aggregated real-time customers' application pattern to the adaptive calibration. Big Data technologies enable OEMs to adjust a product's calibration according to its operating condition. The customized calibration not only provides value to end users, but also can prevent and minimize product defects.
2. Instead of focusing on one product life-cycle, Big Data technologies enable OEMs and suppliers to adopt circular-economy development. With expanded data support, OEMs and suppliers can pre-define reuse or recycle features in the early product development phase. The circular-economy will decouple OEMs in the automotive industry from raw materials constraints.

BIG DATA APPLICATION STRATEGY- ENSURE WIN-WIN SITUATION IN CIRCULAR ECONOMY

In a typical New Product Introduction (NPI) process in the automotive industry, a product is defined by components that meet specific functions and features. There is not a strict differentiation between consumable and durable components. The design and development goals are focused on one product life cycle.

Remanufacturing practice is one of the techniques utilized by the automotive industry to save cost and extend product life. However, there is a trade-off curve between initial NPI components cost and remanufacturing capability. This relationship has been pointed out and investigated by the automotive industry since 1960. Holzwasser, H. summarized the commonly remanufactured replacement parts since 1920 in his paper [3]. He also pointed out: "A threat to the remanufacturing alternative is engineering that seeks weight reduction and low cost in components rather than durability and hence remanufacturability." The threat that he witnessed 30 years ago still exists in the current automotive industry, where more and more OEMs pursue low-cost manufacturing processes.

It is a challenging process to locate the optimum point in the trade-off curve between initial NPI components cost and remanufacturing capability. Many maintenance and service practices have adopted remanufactured powertrain components in the automotive industry. The remanufacturing process typically ensures better quality control and lower total cost compared to a rebuilding process [4].

Wallis, J., and Ferrone, C., listed the difference between the remanufacturing and rebuilding process in their review [4]: "The start of the remanufacturing process begins with the receipt of a core. The core is identified and inspected to determine if it meets the core acceptance criteria. The component then proceeds to the teardown phase where disassembly occurs. At this point the component loses its identity. Wear parts are discarded." The effectiveness of the remanufacturing process in the review [4] is based on the assumption that the core can be easily separated into the consumable and durable components. This is not always possible in the automotive industry; hence, the circular economy concept has to be implemented in the design phase of a product.

Life Cycle Planning - Design and Calibration for Remanufacturability

Extending the life cycle of products in the automotive industry provides benefits to OEMs, purchasers, end users and general society. Before Big Data technologies were developed recently, there were many guidelines and case studies regarding the remanufacturing process in the automotive engineering sector. Beretta, J., Costello, M., et al., summarized the remanufacturing benefits to OEMs [5]. However, the full utilization of these benefits depends on the successful parts salvage with low cost. If a component cannot be separated into the consumable and durable parts, more cost will be incurred during the remanufacturing process.

Traditional automotive technologies adopt many design techniques to improve remanufacturability of components, subsystems, systems and vehicles. For example, special designs will allow wear to occur on the top edge of piston rings instead of liners. In this way, liners and pistons can be easily reprocessed during remanufacturing, while piston rings are replaced. However, a traditional remanufacturing process is disconnected from the product calibration process. A rule of thumb is used to estimate the wearing level of components without life-cycle wearing data support.

A calibration process also dramatically affects product life cycle planning. For example, the engine calibration process is the final step in determining engine performance and emissions. The calibration process has the following characteristics. First, an engine calibration solution can be easily adjusted to validate the optimized solution on one sample engine, but it is difficult to validate the proposed solution on the engine population. Second, the engine calibration is focused on overall system performance, and subsystems' calibration is assumed to bring all subsystems' performance to the nominal value.

When Engine Control Module (ECM) notices a change of speed and load, control parameters are interpolated according to control maps. These control maps are created in the engine calibration process and will be used for all engines of the same family. Typical ECM parameters are listed in Table 3.

Table 3. ECM Control Parameters

ECM Control	Description
1	Multiple Injection Type
2	Main Injection Timing
3	Main Injection Pressure
4	Exhaust Gas Recirculation Level
5	Intake Manifold Air Pressure
6	Pilot Injection Timing
7	Pilot Injection Fuel Quantity
8	Post Injection Timing
9	Post Injection Fuel Quantity
10	Diesel Exhaust Fluid (DEF) Quantity

The goal of calibration is to locate a combination of ECM parameter values, so that both engine performance requirements and emission requirements are met. NO_x emission is one of common emissions for both diesel and gasoline engines. There are many theoretic studies related to the NO_x emission formation [6, 7]. The thermal or Zeldovich mechanism is widely used in diesel engine simulation due to its simplicity. The Fenimore mechanism is widely used in the rich combustion condition, and N_2O intermediate mechanism is more suitable to low-temperature lean combustion.

According to all theoretical studies and calibration tests, start of ignition is a critical parameter to control the NO_x emission; hence, the injection timing for diesel engines and spark ignition timing for gasoline engines are determined during the typical engine calibration process. These calibration tests are based on one engine sample or several engine samples. Since there are unavoidable manufacturing variations, other procedures will be adopted to tune fuel quantities for each engine to meet power requirements.

Subsystems' manufacturing tolerance impacts final engine performance and calibration. For example, injectors could deliver different fuel quantities at the same ECM parameters. Figure 1 illustrates the quality distribution of injectors. Injectors' end-of-line tests are conducted according to certain criteria. Trim factors are also used to bring each injector's performance close to the nominal values.

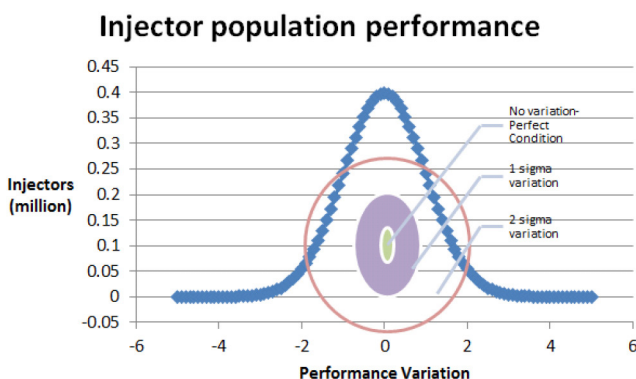


Figure 1. Injectors' Performance at Certain Checking Conditions in End-of-line Tests

The start of diesel fuel injection is fixed to ensure emission compliance for all engines in the same family. Fuel quantities and injection duration can be tuned for different injectors and diesel engines to compensate manufacturing variation. This practice could lead to the different End of Injection (EOI) for different diesel engines.

It is well known that there is a relationship between the EOI and soot rate in oil for diesel engines. The soot rate in oil impacts components wearing of diesel engines. Figure 2 illustrates the typical relationship. Due to the different EOI, different engines actually have different soot percentage in oil during normal engine working cycles. These small differences accumulate through whole engine working life, and it will finally lead to different wearing levels at the end of a product's life.

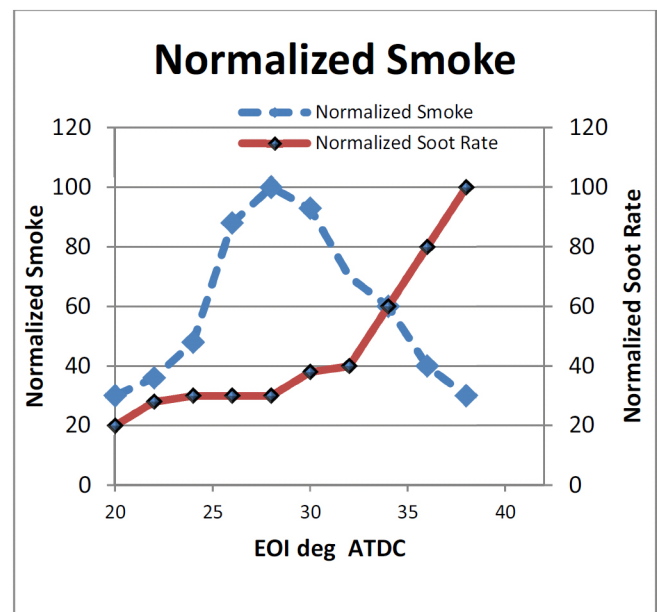


Figure 2. EOI vs. Normalized Soot Rate

Given the above scenario, each engine actually has its own wearing process, although OEMs typically suggest the common oil life and maintenance schedules for all engines that belong to the same engine model. Dealers have already utilized maintenance logs for each vehicle to customize their service plans. However, the detailed ECM control and tuning information are typically not available to dealers.

All subsystems' and engines' calibration and tuning information have been available for decades, and there are also many empirical models to estimate the oil soot and engine wear based on engine cycles and ECM control parameters. However, OEMs rarely use them to customize remanufacturing design and salvage techniques for each engine. The reason is that too many factors affect the effectiveness to utilize the calibration and tuning information, such as vehicle driving cycles, oil change frequency and repairs or premature replacements. Some useful information is generated from end users' work cycle logs, and others are