Futuring the Next Industrial Revolution

By Boris Zlotin and Alla Zusman, Ideation International Inc.

and

Larry R. Smith, Ford Motor Company

"Machiavelli had it right. Change is a tough gig. It's vexing, wrenching, risky. Change lies at the heart of what we expect our leaders to produce. But the creation of new values, of different ways of thinking and acting, is the most difficult task that any leader can undertake."

-Keith Hammond

Change happens. It may be a shift in our way of thinking, a new paradigm (yesterday we thought eating eggs was healthful, today we are worried about cholesterol), the introduction of a new technology (the development of personal computers), or a competitive innovation (Chrysler introduces a minivan with doors on both sides). Typically, changes are small incremental improvements over what we do today. Periodically, the change is massive. In the marketplace, massive transformations that impact society (client needs and expectations), technology, and business position (market share), are called "structural crises," natural cycles in the evolution of systems.

In business, those who lead the introduction of a structural crisis or at least foresee the crisis and quickly adapt to it are winners. Those who lag behind, either not seeing the change or perhaps hoping the change is only temporary may lose everything. In their initial stages, these changes are barely visible -- a complex interaction of technology, psychology, and philosophy that is difficult to discern with market research. Then suddenly the phenomenon appears and, like a tornado, quickly grows stronger and sweeps everything in its path, transforming the organization of production processes, the structure of consumption, the structure of power, inter-personal communications, and even family relations.

Typically, the automotive industry, especially in the United States, is one of the first industries to be affected. This paper will explore the impact of "structural crisis" on the automobile industry in the past, the nature of how structural crisis evolves, and the application of these ideas into an "E" Paradigm (1,2) -- the next industrial revolution.

History: Evolutionary Cycles or Structural Crises in the Automotive Industry

On June 4, 1896, Henry Ford was so excited that he had barely slept in the past forty-eight hours (3,4). Having overlooked the fact that the door of the shed in which he built his first automobile was too small for his car to exit, Henry had to take an ax and knock out a portion of a brick wall to let the car out. Because the handful of vehicles built in those days were known to scare horses and make noise, Henry needed a special permit to drive in the streets. On his first ride, Henry's friend, James Bishop, pedaled ahead of Henry on a bike to "warn off pedestrians." Henry later drove to his father's farm, but William Ford refused to ride in Henry's car. Why, he asked, should he risk his life for such a brief thrill?

Henry's first vehicle was a combination of ideas from the carriage industry, the bicycle industry, and gas engines. For some time, experimenters were trying to put a gas engine on a bicycle in some form or other. In fact, Henry called his first vehicle a "quadricycle." Later, on a ride with a newspaper reporter from the *Detroit News Tribune*, Henry and the reporter passed a harness shop. "His trade is doomed," Ford said. The introduction of the "horseless carriage" gave birth to the automobile industry, a structural crisis that introduced massive changes in society. In fact, society changed so much that Henry later built Greenfield Village, a full-scale open-air museum of what life before the automobile was like.

Although Henry Ford was one of the first to be involved with automobiles, his true contribution is associated with the structural crisis of bringing "mass production" to the auto industry. Mass production, Henry said, was "the new messiah" (4). With the introduction of the Model T or "Tin Lizzie" in 1908, Henry achieved his dream of providing a car for the multitude. A "farmer's car," the Tin Lizzie design was simple, durable, compact, and light, with no frills, and it was absolutely affordable. When first introduced, it took twelve and a half hours to make one car; the price was $780. Twelve years later, Henry was making one car a minute, and by 1925, one every ten seconds. By 1914, the price of the Model T was $360. That year, Henry employed 13,000 people and produced 267,720 cars; the other 299 American auto companies combined produced only 286,770 cars with 66,350 employees. Henry's market share went from 9.4% in 1908 to 20.3% in 1911, to 39.6% in 1913, to 48% in 1914. The advertising slogan was, "Watch the Fords go by." Altogether, Henry sold 15,456,868 Model Ts. Not only was it a huge business success, it was the beginning of a social revolution. Henry realized that with mass production he had achieved a breakthrough for the common man. He wrote, "Mass production precedes mass consumption, and makes it possible by reducing costs and thus permitting both greater use-convenience and price-convenience" (4).

By 1924, Henry Ford was himself becoming a victim of a structural crisis. What Henry had done so well, rival companies were doing as well or better, with more technological innovations and better business systems and marketing. While Henry stood pat with the traditional Tin Lizzie, General Motors coordinated activities among its several divisions in order to provide a car for "every purse and purpose" (5). Competitors like Chevrolet were introducing improvements such as a self-starting ignition system, six cylinder engine, balloon tires, improved (hydraulic) brakes, thermostats for heaters, better electrical and suspension systems, and colors. People wanted style, speed, and comfort. Ford's only response was to cut price -- by 1923, the Model T sold for $285. In 1921, a number of dealers asked Ford if he would change the color of the Model T. Henry replied, "You can have any color you want, boys, as long as it's black" (3). In 1926, Ford sales dropped from 1.87 million to 1.67 million, while Chevrolet sales doubled from 280,000 to 400,000. Fortune magazine called Henry, "the world's worst salesman." In 1936, GM had 43% of the automotive market, Chrysler 25%, and Ford 22% (5). Some thought that without the stimulus of WWII and the defense industry work it brought to Ford, the company would have failed completely (4).

1946 was the beginning of a post-war economic boom in the United States. Cars meant more than just transportation -- with tail fins, whitewall tires, and two-tone color schemes, they became expressions of the ego, vehicles for status, escapism, dreams. Families could soon afford to have two cars per household. Ford began with about 19% of the U.S. market share, competing with GM and Chrysler, as well as with a number of nameplates that would not survive this structural crisis: Nash, Hudson, Kaiser-Fraser, Willys, Packard, and Studebaker (3). With the Whiz Kids, a group of U.S. Army Air Force Officers who had worked together in the Office of Statistical Control, Henry Ford II ushered in a system of rigorous cost analysis, financial control, and Management by Results (4). Ford dramatically improved labor relations with the United Auto Workers, and with products like the Thunderbird, Ford's market share improved to 31% by 1954, second only to General Motors. In both 1965 and 1966, the Mustang alone sold more than half a million units -- 6.1% of all cars sold in North America and 78.2% of the small-sporty segment (3).

The first three years of 1980 were brutal for the U.S. automobile industry. Sales stalled as America experienced its second oil crisis, one brought about when the Shah of Iran was displaced by the Ayatollah Khomeini. The situation at Chrysler soon became critical. While the nation was focused on Chrysler's near-bankruptcy and its negotiation of a government bailout, Ford Motor Company was experiencing extreme problems of its own. In the first three years of 1980, Ford lost $3.3 billion -- 43% of Ford's net worth and more money than any corporation had experienced up to that point in time. Market share fell from 23.6% in 1978 to 16.6% in 1981 (7). As the price of fuel doubled and Americans experienced long lines at gas stations, Japanese cars were selling like hotcakes. Some Japanese models had waiting lists of up to a year, and the U.S. market share for Japanese automobiles rose to over 21% in 1980. It was then that the U.S. public discovered that Japanese cars were very good cars. They "felt right" and had far fewer problems than vehicles manufactured by U.S. automakers.

Alan Gilmour, Ford Vice President of Finance, said, “It became very clear to our management team that we were uncompetitive in every element of our business. We didn’t have the cars people wanted to buy. We didn’t have good quality and our costs were too high. Furthermore, we had poor relationships with practically everyone – our employees, dealers, suppliers, and the government” (7). This most recent structural crisis began with an energy crisis and turned into a quality crisis. Ford invited Dr. W. Edwards Deming, a management consultant who specialized in improving product quality and competitive position, to work with the management team, as the “Big Three” battled Japanese, Korean, and European manufacturers for quality, customer satisfaction, and market share. This battle continues today.

A summary of these major structural crises, or evolutionary cycles, is shown in Figure 1.

Figure 1: Automotive Industry System Evolution

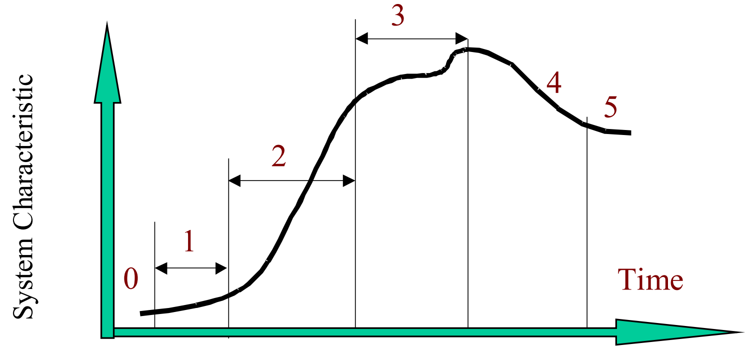
Year	Structural Crisis	Consumer Needs	Technology	Business Position
1910-1920	Mass production without Variety	A "farmer's car" for the multitude	Assembly line	Ford has 48% of U.S. market share by 1914
1920-1945	Mass production with Variety	One car for every purse and purpose	Innovations for style, speed, and comfort	GM has 43% of U.S. market share by 1936
1945-1980	U.S. Post-War economic boom	Two-car families Vehicle for status, escapism, dreams	Management by Results with cost analysis and control	U.S. Big Three established: GM, Ford, Chrysler
1980-present	Energy, Quality, Customer Satisfaction	Dependable, durable, fuel-efficient vehicle	Quality tools and methods; Fuel and emission controls	Significant market share to Japanese, Korean, and European manufacturers

How Systems Evolve

The history of structural crisis in the automobile industry is useful in understanding how systems evolve. Genrich Altshuller made principles associated with the evolution of systems a significant part of his methodology for innovative problem solving, called TRIZ [a Russian acronym for "Theory of Inventive Problem Solving" (8)]. Let's explore some of these principles.

First, like people, systems tend to age over time, with their own growth and age curve associated with birth, youth, and maturity. For example, consider the development of Mass Production without Variation, as discussed above. At first, Henry Ford was the only person with the idea. As he began to implement it, production was relatively slow -- one vehicle every twelve and a half hours. Then the idea seemed to catch hold. Many improvements were made -- one car every minute by 1920 and one car every ten seconds by 1925 -- and other manufacturers adopted the idea of mass production. Then the system matured to a point where new improvements became relatively rare. Finally, the use of Mass Production without Variation declined because vehicles without variation could not be sold. This system lifecycle, called an "S-Curve," is generic and is illustrated in Figure 2.

Figure 2: A Lifecycle in System Evolution



Stage 0 - A system does not yet exist but important conditions for its emergence are developing.

Stage 1 - A new system appears because of a high-level invention and begins to develop slowly.

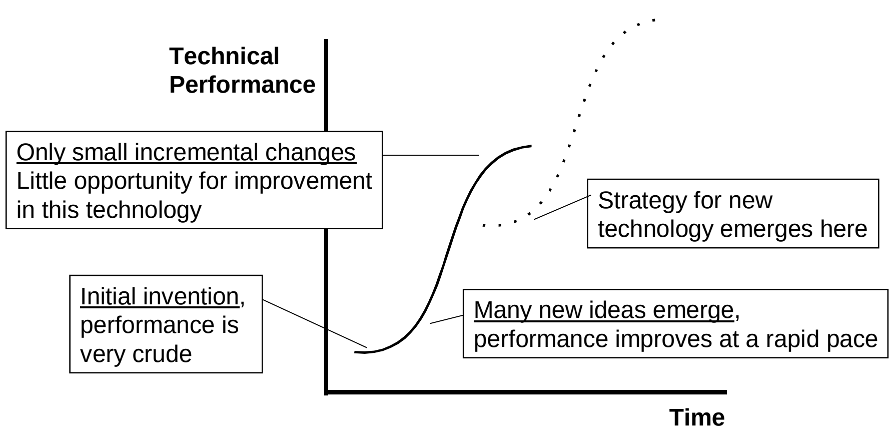
Stage 2 - Begins when society recognizes the value of the new system.

Stage 3 - Begins when the resources on which the original system is based are mostly exhausted.

Stage 4 - Begins when a new system (or the next generation of the current system) emerges to replace the existing one.

Stage 5 - Begins if the new system does not completely replace the existing system, which still has limited application.

Figure 3: Technological Evolution



This example also illustrates another principle of system evolution -- that systems evolve over time in a series of S-Curves. Consider Figure 3. As the development of Mass Production without Variation began to slow down, a higher evolution of the system emerged, Mass Production with Variation. Depending on the situation, the newer level of system evolution may displace the older level, or the older level may continue at a much-reduced volume. For example, when Mass Production was introduced, it dominated the previous level of system evolution, associated with custom-made vehicles or craftsmanship. However, custom-made vehicles are still manufactured in small volumes today.

A third principle associated with the evolution of systems -- the concept of Ideality -- may also be readily observed by considering the history of automotive evolution. Altshuller defined Ideality as the sum of all the useful functions of a system divided by the sum of all the harmful functions of a system. In each cycle of evolution, the system evolves toward greater Ideality. For an automotive system, examples of useful functions, commonly called Things Gone Right (TGR), include transportation with information, style, entertainment, climate control, comfort, speed, tow or carrying capacity, movement over deep snow or off-road, etc. Examples of harmful functions, called Things Gone Wrong (TGW), include pollution or poor exterior air quality, poor interior air quality, safety and crash concerns, operating cost, use of fuel and energy, quality issues (especially items associated with vehicle dependability), vehicle concerns with reliability and robustness over time, dependability concerns, and recyclability/reuse of materials/parts at vehicle end-of-life.

Note that every transition in Figure 1 improved Ideality. For example, consider again the transition from Mass Production without Variation to Mass Production with Variation. Improvements in useful functions were associated with style, comfort, speed, and convenience. In addition some harmful functions associated with lack of safety, quality, reliability, and dependability were made less bad. Other harmful functions increased: manufacturing cost, energy consumption, complexity, some additional quality concerns with implementation of new technology, and some additional safety concerns with vehicles moving much faster than before. Nevertheless, the net result was that, in the perception of society at that time, Ideality increased -- so much so, that if a manufacturer did not adapt to the new paradigm, it would soon be out of business.

TRIZ contains other tools associated with understanding and futuring system evolution. Altshuller called these "Laws and Lines of Evolution" (8). "The emergence and implementation of innovation is not random or haphazard, but rather are dictated by certain general evolutionary patterns governing the creation of artificial systems" (9). Boris Zlotin and Alla Zusman and their colleagues at Ideation have refined these thoughts and integrated them into a systematic approach aimed at predicting the future generation of a system by inventing it (9). They call their approach "Directed Evolution." The ideas associated with the next section of this paper, futuring the next industrial revolution, are a synthesis of work using this methodology. It is appropriate to note that this methodology can be applied at any level of a system. Altshuller liked to create a nine-panel chart, looking at the super-system, system, and sub-system in the past and the present, and then projecting the future. Although there is tremendous opportunity in considering the evolution of automotive sub-systems -- some automotive suppliers are currently using Directed Evolution to put "patent fences" around where they feel their sub-systems must evolve-- this paper will consider the automobile only as a system.

Futuring the Next Industrial Revolution

When many people consider the automotive industry in light of the S-Curve of system evolution (Figure 1), they initially think that the auto industry is stagnant, an old traditional system on the third stage (maturity) of development. A closer look indicates that such an analysis is absolutely wrong. For the past ten years, the auto industry has begun a transition from a vehicle viewed as a "less-harmful electro-mechanical" system to an "E" Paradigm system, where "E" stands for Environment, Electronic/Communication/ Information, and Energy (1,2).

The E=Environment portion of the next industrial revolution involves a transition from making vehicles less harmful to the environment, to making vehicles positive for the environment. For the current evolutionary-cycle, the thinking is: "let's make the product less harmful to the environment." We use expensive devices like catalytic converters to minimize emissions of carbon monoxide, hydrocarbons, and nitrous oxides. Recycling (despite significant progress in the past ten years, only 1045 pounds out of every

10,000 pounds of raw material used to manufacture a vehicle is currently reused) and carbon dioxide emissions (global warming) represent huge potential issues. Today's materials are essentially chosen without considering the total life-cycle cost, including end-of-life disposal -- most waste from materials like PVC are disposed in toxic landfills. Vehicle interior air quality is also an issue. Fogging substances (from plasticizers, catalysts, flame retardants, and releasing agents), odorous substances (from elastomers containing amines and sulphur compounds, and resins containing phenols, aldehyde, and ketones) and volatile organic compounds (from plastic manufacturing residue solvents, polymerization monomers, and adhesive/sealer residues) create a "new car smell," that may also affect consumer health. Potential health effects of currently used materials include carcinogenicity, endocrine disruption, immune system disruption, allergenicity, skin/mucous irritation, and chronic/acute toxicity. From the standpoint of Ideality, there is a huge potential in addressing harmful functions associated with environmental concerns.

Now let's explore a new paradigm associated with making vehicles "positive for the environment," as championed by Bill McDonough and Michael Braungart (10, 11) of McDonough Braungart Design Chemistry (MBDC). This paradigm focuses on activities that are regenerative (versus less bad) using principles of "Eco-Effective Design." The goals of Eco-Effective Design are to meet and exceed established quality, economic, and technical performance criteria -- in other words, don't lose any of the benefits from previous evolutionary cycles -- while fostering healthy and prosperous conditions for humans and ecological systems by reutilizing materials/components in natural biological or technical cycles. Biological cycles refer to the biological metabolism of nature that reutilizes organic waste products of one life cycle as biological nutrients for another life cycle. Technical cycles refer to the reuse of components and other technical waste products (polymers, metals, organic solvents, etc.) as nutrients for another generation of products. Eco-Effective Design involves designing products to fit these two cycles to recapture value over and over.

To better understand what Eco-Effective Design is all about, consider how American Indians utilized buffalo. Literally, nothing in a buffalo was waste -- every part of the buffalo was useful. The hide was used for making clothes, shelter, and rugs. Meat was used for food. Bones were used for decorations and tools. Even dried dung was used as fuel for fires. Every use promoted sustainability of the system in a healthful, renewable way. Similarly, every part of a vehicle must be designed to add value at end-of-life. From an Ideality point of view, Eco-Effective Design presents huge opportunities associated with reducing cost, minimizing waste, and reducing energy.

How would Eco-Effective Design approach emission issues? First, the catalytic converter must go -- besides the expense, the converter itself contains noble metals that are not a healthful part of any biological cycle. If you think about the internal combustion engine as a chemical factory, what products could this factory produce that are biological or technical nutrients? We don't want carbon dioxide in the atmosphere, but carbon black is a useful substance --many companies associated with rubber and plastic manufacturing burn fuel just to produce carbon black. Could we design a vehicle that converts fuel to carbon black, water, and hydrogen, collect the carbon black and water, and use hydrogen to fuel the internal combustion engine? Bill McDonough has actually suggested that the water be retained, mixed with some carbon dioxide, so that you could have "Perrier" on tap. What about nitrous oxides? Michael Braungart suggests that instead of minimizing these oxides, why not make as many of them as you can, collect them in an on-board "scrubber" and use them as fertilizer? As you can see, this is a completely different paradigm that opens up new possibilities for exploration.

MBDC has developed a strategy and methodology for Eco-Effective Design of any product. The strategy involves:

- Appropriate materials selection, especially eliminating materials and substances in the product and process that pose a risk to human health,
- Designing for Recycling (DfR) – design some components for refurbishment and reuse; design others to use homogeneous materials capable of high-value recycling,
- Designing for Disassembly (DfD) – simplified modular design using standard fasteners and easy-to-release disassembly methods.

Increased use of recycled materials, European End-of-Life legislation concerning increased use of recycled materials and decreased use of hazardous materials, ISO 14000, and the work of companies like MBDC indicate that the "E" = Environment paradigm shift has already begun. From a TRIZ perspective, our choice is between system decline and sustainable growth. "If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continued unchanged, the limits to growth on this planet will be reached sometime within the next 100 years. The most probable result will be a sudden and uncontrollable decline in both population and industrial capacity" (12).

The E=Electronic/Communication/Information portion of the next industrial revolution involves a transition from vehicles as "machines for driving" to vehicles as "machines for living" (13). More and more, people are viewing their vehicles as part of their personal living space, including use of vehicles as a mobile office. With improvements in electronic and web-based technology, the capability now exists for unprecedented individualization of products and their adaptation to specific consumer needs. In the past decade, one of Altshuller's basic patterns of evolution has been very evident in automotive systems, a pattern associated with increasing vehicle "smartness." Examples of this include:

- Use of on-board computers to enhance engine emissions, fuel economy, and performance
- Advent of functions such as automated headlights, rear sonar to avoid hitting an object while backing-up, automated variable adjustment of power steering efforts for improved "road feel," and cruise control
- Use of computers with air suspension technology to sense the road surface and adjust vehicle ride and handling characteristics accordingly, including: adjustment of vehicle height depending on speed (lower the vehicle to improve fuel economy on the highway), and adjustment of body stiffness depending on how quickly the vehicle is turning
- Vastly improved vehicle handling and stopping on slippery surfaces with use of antilock brakes
- Introduction of computer-operated self-diagnostic systems to improve dealer identification of problems and service

From the perspective of TRIZ, Ideality is greatly enhanced with the introduction of these helpful functions.

The transition of the vehicle as a "machine for living" necessitates continued development of the vehicle in the direction of improved electronics/communication/information. Suggestions include:

- Web-based radio (don't lose your favorite radio station over long distances) and in-vehicle MP3 systems
- Enhanced vehicle system performance as different vehicle sub-systems are linked in an internal information network
- Development of the personal "cell" phone as driver identification, allowing different levels of access to the vehicle for different family members, and automated adjustment to preferred comfort/entertainment settings
- Development of the "cell" phone as a part of a global communication system which could enable features such as: verbal communication with the vehicle; automated payment of vehicle wash fees, road tolls, and parking fees; in-vehicle internet access; and GPS navigation/routing to avoid local traffic
- Enhanced safety with automated, lightning-fast, "smart" reaction for accident avoidance
- Possibility of automated vehicle control: on special long-distance highways, for parallel parking, and driving on standardized daily routes
- Increased vehicle self-service, possibly self-repair
- Use of E-commerce to dramatically change and enhance the way vehicles are sold, serviced, and delivered

The E=Energy aspect of the next industrial revolution involves a rapid and drastic increase in the efficiency with which materials and energy are used (14). It is a transition from managing energy and usage in a local sub-system at this point in time to managing energy and usage in the global ecosystem for the entire product life cycle (1,2). Ideality is a function of all costs, all benefits, and all harm in the entire ecosystem for the cradle-to-cradle cycle (remember, in eco-effective design, all components and technical waste act as nutrients for the next product generation) of the product. Only when total life cycle considerations are assessed, can the correct decision be made with regard to true cost and true energy usage.

Suppose I have a choice of materials for a vehicle headliner. I can make the headliner out of PVC, or I can make the headliner out of polypropylene. The decision may appear to be easy. PVC is less expensive than polypropylene, so I choose PVC. However, there may be some environmental and health issues associated with manufacturing PVC. Also, when the product life is over, most PVC waste is disposed in hazardous landfills (although PVC is a thermoplastic, it partially decomposes in mechanical recycling, emitting hydrogen chloride (HCl). Feedstock recycling of PVC is also very difficult because HCl formation corrodes steel. Other approaches to feedstock recycling are still in the development phase.) Who pays for the extra costs associated with proper treatment of the materials used to make PVC and with the process used for end-of-life disposal? Perhaps the material cost difference is really a result of a difference in purchased material volume. Now what is the best decision?

Imagine that we are discussing Michael Braungart's idea of using an on-board reformer to convert fuel to hydrogen, water, and carbon black. If I assume that I can put whatever amount of carbon dioxide into the atmosphere I like, then the fuel reformer looks like a bad idea. However, assume that the earth is not a big place and that I need to manage the entire eco-system. When I put carbon dioxide in, I must also take some out. How will I do this? Plant trees? How many and where? Can I build a machine that can extract carbon from the atmosphere? How would that work? How much does it cost? A consideration of the total life cycle energy costs may provide a different answer.

Suppose I have a situation where I compare the energy usage of an electric engine versus an internal combustion engine. If I assume that electricity is free and that I don't have to dispose of the battery, the decision is easy. Suppose that the electricity comes from burning high-sulphur coal? If I need to clean up emissions associated with creating the electricity, now what becomes the best choice? Today there is a significant amount of research on fuel cells, hybrid vehicles, electric vehicles, etc. Only when a total life cycle model of energy and costs associated with materials choices, manufacturing and assembly processes, operating and disposal requirements are carefully considered, can the best decision be made.

Paradigm "E" … A Disassembly Line Brings It All Together

How will the different aspects of the "E" Paradigm work together to create the next industrial revolution? One possible scenario, proposed by Michael Braungart, involves the concept of a disassembly line. The disassembly line idea proposes that:

- The vehicle is modularly designed for rapid disassembly and replacement/refurbishment of key components
- The transportation provider owns the vehicle and takes responsibility for maintenance, repair, recycling, refurbishment, and freshening of style, features, performance, and function.
- The consumer contracts for vehicle use with options to upgrade features on demand

Imagine a future where customers do not own their vehicles (Michael Braungart questions why would they want to own thousands of chemicals); instead they contract for services with a transportation provider (E-commerce, of course!). This provider assumes complete responsibility for the product, and all the materials and chemicals in the product, from cradle-to-cradle. Since the provider now has the responsibility of paying for landfill costs and can reap the benefits of recycling, the financial incentives align with a strategy of being positive for the environment. The provider will want to make sure that the maximum benefit is obtained from each component. For example, if the provider knows that components like steering gears, axels, and transmissions are made from designs which will not change in the near future, it makes sense to spend some money to make sure these components will last a very long time and can be reused from vehicle to vehicle with minor refurbishment. Other components, perhaps associated with style that could change quickly, would be made out of materials that could easily be recycled. Local to the customer, the provider would establish small disassembly/assembly shops where vehicles could be brought in, the latest features (especially electronic!) and styles added to the vehicle, and then the vehicle returned to the customer.

To make the disassembly idea work, the vehicle must be designed in modules in which the old module can be quickly removed and a new module quickly substituted in its place. Designing for disassembly will make designing for assembly more efficient and fits with the current strategy of using full-service suppliers to provide the different modules. The transportation provider then has the ability to make sure the customer always has a vehicle that looks and acts like new. If the provider knows certain bushings will begin to wear at a particular mileage or time, it can simply disassemble and recycle the old bushings and replace them at the disassembly shop before a problem occurs. Maintenance schedules could be established so that the long-term quality of the vehicle --a significant concern in today's evolutionary cycle -- is never an issue. Furthermore, fixing accidents would be a breeze. There are tremendous advantages here for the consumer. If the consumer wants to upgrade (add options to) the vehicle or change from an SUV to a Pick-up, it is a simple matter of scheduling time (E-commerce, of course, used to make the order and adjust the contract) to have the old module (perhaps the SUV module) removed and the new module (perhaps the Pick-up) added. The latest enhancements for style, features, colors, and energy-use could also be quickly added to the vehicle. Michael Braungart suggests that the provider also take responsibility for energy use; as part of the consumer contract, the consumer would obtain all fuel, etc. as part of the lease fee. This gives the provider incentive to make the healthiest "E" Paradigm decisions with regard to energy.

The disassembly scenario could easily satisfy the system evolution requirements for all aspects of the "E" Paradigm while improving Ideality with the following advantages: extended useful vehicle life, assured dependability, locked-in customer loyalty by providing the consumer a great product with great service, eco-effective life-cycle management of components and materials, energy savings, and the potential for provider profits -- a winning situation on all sides. As with other structural crises or cycles of system evolution, there will be profound impacts in the areas of client needs and expectations (including methods of sales and service), technology (serious changes in design, manufacturing, and assembly/disassembly methods), and business position (market share).

With the addition to the market place of companies like Visteon and Delphi, the market share discussion is interesting. These companies have the resources to develop and market their own vehicles in a way that could usher in the new paradigm. Change is coming, and we know what kind of changes are coming. Whether today's companies will be able to compete in the next evolutionary cycle depends on how they prepare today. There is an opportunity to be a leader, to make these changes in a way that is comfortable now, but will cause trouble for your competitors later. Another strategy is to sit and wait and hope it does not happen. When the change then happens, the provider must react quickly -- perhaps with timing and methods that are expensive and not comfortable -- or go out of business. Every structural crisis in the past has acted like a window, allowing the entrance of new strong competitors. The next industrial revolution will not be any different. In addition to the possibility of Visteon or Delphi, the coming change will offer opportunities for companies from areas such as China, Russia, Eastern-Europe, and South America to become major market players.

References

1. Tipnis, Vijay A. "Challenges in Product Strategy, Product Planning, and Technology Development for Product Life Cycle Design," *Annals of the CIRP*, Vol. 41/1, 1994, p. 157-162.

2. Tipnis, Vijay A. "Evolving Issues in Product Life Cycle Design," *Annals of the CIRP*, Vol. 42/1, 1993, p. 169-173.

3. Lacey, Robert *Ford, The Men And The Machine*, Little, Brown and Company, Boston, 1986.

4. Halberstam, David *The Reckoning*, William Morrow and Company, Inc., New York, 1986.

5. Johnson, Thomas H., and Broms, Anders *Profit Beyond Measure*, The Free Press, New York, 2000.

6. Collier, Peter, and Horowitz, David *The Fords, An American Epic*, Summit Books, New York, 1987.

7. Shook, Robert L. *Turnaround, The New Ford Motor Company*, Prentice Hall, New York, 1990.

8. Altshuller, Genrich *The Forty Principles*, Translated by Lev Shulyak and Steve Rodman, Technical Innovation Center, Worchester, MA, 1994.

9. Suzman, Alla, and Zlotin, Boris "Patterns of Evolution", A tutorial for TRIZcon2001 held on March 25, 2001, Woodland Hills, CA, Available from the Altshuller Institute for TRIZ Studies, Worchester, MA, (see www.aitriz.org).

10. Interview with Michael Braungart and Bill McDonough, *Green@Work* magazine, May, 2000.

11. Braungart, Michael, and McDonough, Bill "The NEXT Industrial Revolution," *Atlantic Monthly* magazine, Vol. 282, No. 4, October, 1998.

12. Meadows, Donella H., Meadows, Dennis L., Randers, Jorgen, and Behrens III, William W. *Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*, Signet Books, 1972.

13. The architect LeCorbusier first applied this thought to designs for homes.

14. Meadows, Donella H., & Meadows, Dennis L. *Beyond The Limits: Confronting Global Collapse, Envisioning a Sustainable Future*, Chelsa Green Publishing Company, 1992.