THE RECIPE FOR TENFOLD RESOURCE PRODUCTIVITY IMPROVEMENT

THE CAR IS SUCH A MATURE TECHNOLOGY that we are approaching the 250th anniversary of the first auto accident. In 1771, a Frenchman used an early, coal-fired steam engine to haul cannons but lost control and crashed into a wall. Since that first auto-related shout of *Sacre bleu*! (or whatever French equivalent he used for "We're all gonna die!"), the auto industry has offered an instructive look at how things can go right – and then wrong – and then right again – when it comes to major industrial shifts.

The car industry also shows the power of the five principles that we'll cover in this chapter and that are the first areas a company should look at when thinking through how to win the resource revolution. Those five principles are:

1. Finding opportunities to substitute away from scarce resources.
2. Eliminating waste throughout the system, from production through end use.
3. Increasing "circularity" – upgrading, reusing, or recycling products.
4. Optimizing efficiency, convenience, safety, and reliability.
5. Moving products, services, and the processes that develop or deliver them out of the physical world and into the virtual realm.

After motorized travel showed early promise in the mid-1800s, a backlash developed. Cars were classified as "road locomotives," and speeds were restricted to 4 mph in the country and 2 mph in towns and cities where, for good measure, a man carrying a red flag had to walk in front of each car.

There were incorrect assumptions about how the technology would develop. Many worried, for instance, that the adoption of cars would be limited because, after all, at some point the world would run out of chauffeurs to drive them. Many also initially assumed that cars would be electric, if only so that a driver didn't have to turn a crank to provide the compression that would start a gasoline engine – while risking a kick from the crank that broke many an arm.

Finally, in the late 1800s and early 1900s, the second industrial revolution turned the car into a raging success. Rudolf Diesel invented the internal combustion engine. New forms of “cracking” petroleum provided wide access to gasoline. Henry Ford’s automated assembly line made cars available to the mass market.

Cars spread across the landscape, as did roads and the cities they enabled. The development of the oil industry and the automobile saved New York and London from being buried in manure, saved whale populations worldwide, allowed suburbs to develop, allowed fresh produce to be delivered to cities, and opened a new era of dramatic economic growth.

Although many observers argue that the world will soon have to spend more capital and get less of a product or service in return, the history of the automobile in the early twentieth century highlights the fact that resource revolutions are actually about providing far more capability at sharply lower cost. Where steam-powered cars had 2 or 3 horsepower (hp), a 30-mile range, and a top speed of 12 mph, the Model T generated 20 hp, had a 250-mile range (getting 25 mpg) and had a top speed of 45 mph. Yet Ford’s cars cost a fraction of what steam-powered vehicles cost. The technologies and business models that win will deliver dramatically better performance – more output for less input – just as the lightbulb was invented as a way to reduce whale oil use and won by delivering remarkable improvements in health and working hours, making it possible to work after dark at low cost without soot, noxious fumes, and fire hazard.

Henry Ford (1863–1947) with one of his company’s Model T automobiles, c. 1920

In terms of the three economic inputs laid out by Adam Smith, auto- makers have invested huge amounts of capital and have pushed hard on labor productivity in the decades since Ford. Companies have focused on speeding up the assembly line and employing fewer workers, leading to innovations such as the lean production system pioneered by Toyota and necessitating the increased use of robotics in manufacturing. But the pendulum has swung back in the other direction. Having been a paragon of efficiency for so long, cars now have obvious problems that can only be solved by paying attention to Smith's third input: land and natural resources.

Henry Ford defined the current model of car ownership in the early twentieth century. Owning a car became a status symbol. A car represented suburban freedom, adventure, and achievement. The car has evolved into a basic necessity to get around, given the nearly complete lack of mass transit infrastructure in the United States. But, even though the quality of cars and their efficiency have continued to improve, some aspects of car usage have become much less efficient.

Though most cars still have five seats, average occupancy has dropped to 1.6 people per vehicle. American cars have more than tripled in weight from the 1,200 pounds of the Model T to more than 4,000 pounds today. As physicist and environmentalist Amory Lovins has pointed out, less than 1 percent of the energy in a tank of gas really goes toward moving the passenger from point A to point B; the rest is lost in heat, tire wear, and moving hunks of metal and air.

Even worse, most of us own a car mainly to park it 96 percent of the time. Cars are typically the second biggest capital expenditure we make[1] – the first is buying a house – yet they spend almost their entire lives sitting at home or in parking lots. While car companies have innovated in finance – they now lease the car to an individual to park rather than selling it to an individual to park – the basic productivity equation has not changed. The driver still gets precious little use out of the car.

Roads are likewise extremely inefficient. A freeway operating at peak throughput of 2,000 cars per lane per hour is less than 10 percent covered by cars. Add more cars, and congestion drops speeds and reduces throughput. Freeways take up anywhere from 2 to 6 lanes in each direction, 24 hours a day, 365 days a year, even if that full capacity is used only for a few rush-hour periods five days of the week, and sometimes only in one direction. This translates to 4 to 5 percent of the time that roads reach peak throughput if there are no traffic jams. What if we could move 20 times the volume on existing roads or reduce the highway requirements by 90 percent?

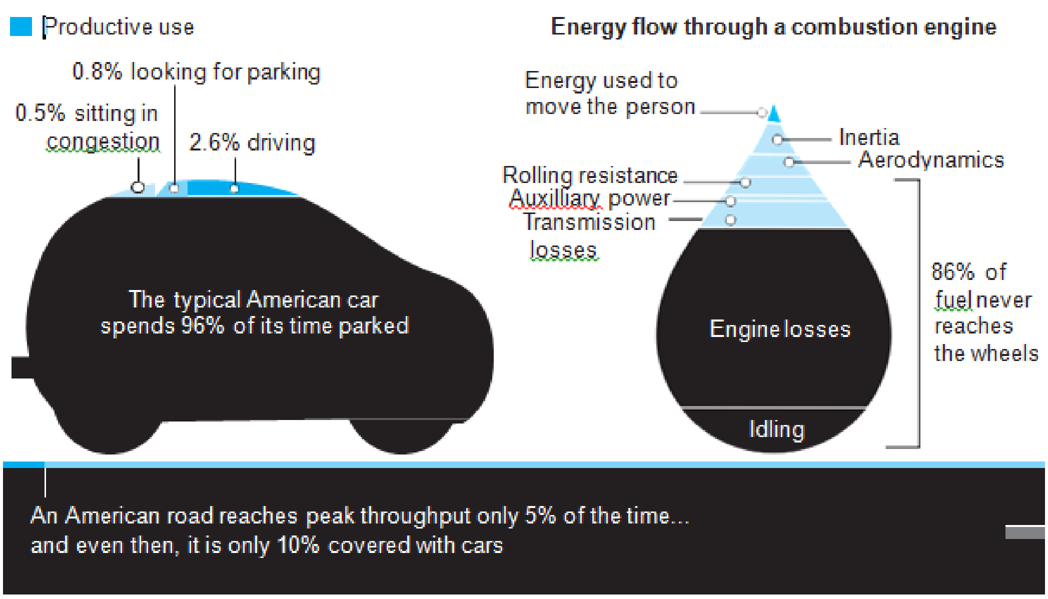
---

[1] Americans devote 17% of their annual spending to transportation, including 5% on gas and 6.1% to buy the vehicle. They also spend 1.4% of GDP of roads at all levels of government, lose 1.6% of GDP sitting in congested traffic, and lose $1,522 per person annually to traffic accidents, which are also the ninth leading cause of death globally.

These problems aren't the kind that can be solved by investing in new equipment or making workers more productive. These problems require that car makers truly rethink their product for the first time in a century.

In the process, they may wind up without internal combustion engines, without individual owners, and potentially even without drivers, while providing breakthroughs in convenience and safety and radical reductions in costs for both consumers and manufacturers.

Waste in fuel, cars, and roads caused by automobile transportation



Companies are already starting to seize the opportunities to optimize car usage. Mobile apps are making it easier to arrange car pools. Zipcar, acquired by Avis in early 2013 for $500 million, offers memberships that let people rent cars cheaply by the hour in major cities; each Zipcar is estimated to replace twenty-one cars in its subscriber base. Uber smoothes out inefficiencies in cab and limo systems by letting people summon a car and driver via a smartphone app. Going even further, RelayRides and Getaround provide marketplaces where individuals can rent their cars to others, rather than just have the cars sit idle. GM is working with RelayRides so renters can receive a code to type into their smartphones that will unlock a car via GM's OnStar; that way, owners can simply leave the keys in the car and avoid having to arrange a meeting to hand them over. BMW and Daimler have started car-sharing programs and publicly said they are transportation companies, not car manufacturers.

Soon enough, roads and other infrastructure will adapt to make cars more efficient, too. Cars will be able to communicate with traffic lights, so they'll know whether they're going to make it before a light turns red and can either maintain speed or slow down and save fuel. Pilot tests by the Department of Transportation found fuel savings as high as 15 percent in urban settings from this sort of communication. Local governments will notify drivers of the nearest empty parking spot via an app on their phones, and drivers will be able to reserve a spot by paying for it even before getting there – 30 percent of the emissions from cars in cities come from people circling the block while trying to find a parking space, so savings on fuel and emissions will be significant. A start-up, Sensity, says it will take advantage of the upgrade of incandescent streetlights to more efficient and longer-lasting LED, and will offer municipalities the opportunity to include sensors in the new streetlights that will monitor and report on the availability of parking spots on streets.

Inrix gathers location information from tens of millions of mobile devices in forty countries, combines the data with all kinds of other information – about concerts, sporting events, impending snowstorms, etc. – and feeds information on traffic flow and optimal routes to drivers through in-car navigation systems, smartphone apps, radio stations, and other devices. Inrix reports that levels of traffic congestion it measures in the United States have been declining steadily since 2010.

Inrix came about because of the sort of simple but profound insight that often fuels a resource revolution. At the time it was founded, municipalities measured traffic flow mostly by digging up roads and installing induction coils, and news organizations paid for helicopters to monitor rush-hour traffic. But Bryan Mistele, the president and CEO of Inrix, and Craig Chapman, CFO, realized they could crowd-source the data gathering and get information for free by drawing on all the sensors that people were already carrying with them. Mistele had a background in the car industry: His first job, at Ford, was building computers that handled the shipping of cars; he then went to work at Microsoft, where he created software for cars. He had seen rapid demand growth in software, but even he was surprised at how quickly the idea for Inrix resonated with people. In 2005, when the company had just six people, he made a presentation to the CEO of one of the two big digital map companies, to try to interest the company in using Inrix data. Half an hour into the presentation, the CEO slammed his hand on the table and stopped the meeting. “Uh-oh,” Mistele thought, “we’re going to get kicked out.” In fact, the CEO of the mapmaker wanted to give Mistele the twelve people in his traffic department in return for certain rights to sell Inrix’s data.

Technology will also reduce accidents greatly, cutting the need for repairs and new cars. At the moment, some 9.4 million cars a year are involved in accidents just in the United States. Simply getting adaptive cruise control into 20 percent of the cars on the road is expected to change the flow of traffic enough to cut the number of traffic accidents sharply. Other automated-driving technologies for parking and crash avoidance, which the big car companies are introducing steadily, will also cut accidents. A recent study in the United States found that 33 percent of drivers didn't even touch the brakes before their collision and that a further 99 percent didn't fully engage the brakes. There is lots of room for improvement by giving cars the capability to apply the brakes automatically in advance of a potential collision.

The path to optimization won't always be straightforward. Uber, for instance, found itself doing battle with the entrenched taxicab oligopolies – a medallion to operate a single taxi in New York City costs about $1 million, so incumbents will fight hard to prevent new types of competition. Taxi companies have had at least occasional success arguing that car services shouldn't be able to use GPS to meter the precise time and distance of a trip, to book a pickup less than thirty minutes ahead of time, or even to allow "electronic hails" at all – in the name of protecting consumers, of course. For instance, when Uber tried to launch in Austin, Texas, to provide free service during the South by Southwest gathering, the local taxi companies sued and launched a high-profile campaign to label Uber a risk to the community. But Uber has made steady progress as the public hooted down the self-serving claims by the taxi companies and the initial sympathetic actions by regulators.

Anti-collision technologies face their own hurdles, mostly because liability issues get tricky once control of a car is taken away from a driver. But, with millions of accidents a year and some 33,000 highway deaths just in the United States – about the same number as from lung cancer, guns, and suicides combined, and an order of magnitude more than war, poison, fires, and falls – the conclusion is inescapable: Good drivers are in a minority. Either the government will eventually intervene to mandate technology that can prevent collisions or someone – likely the insurance companies – will provide incentives that encourage adoption.

While the smart car companies currently focus on optimization, there are also plenty of opportunities to reduce waste. For instance, the adoption of 3-D printing will eventually slash waste. It will no longer be necessary to machine a sheet of steel for a door by "subtractive" manufacturing: punching out a hole for a window, thereby creating a piece of scrap. It will be possible to simply print the door panel in an "additive," or layering, process to produce its final shape. In fact, it will be possible to "print" the whole car body, creating all kinds of possibilities for waste reduction, both in terms of materials and of labor. All sorts of connections will no longer be needed, and material will only be used where it's needed – rather than have doors be of uniform thickness, because that's how sheet metal is produced, each part of the door can be made exactly as thick as required. (We explain the 3-D process and its implications in more depth a little later, in our discussion of waste reduction.)

Car dealer networks will be reinvented, cutting more waste. At the moment, in the United States, car makers take their best guess about what buyers want, and dealers place orders for cars that may then sit on lots for weeks or months. Car dealers are currently protected by state laws that require a car to be sold by an independent dealer who can set a price and make consumers haggle, but the writing is on the wall: When consumers realize how much more convenient it can be to order custom-configured cars on the Internet for home delivery, laws will change so that car makers will eventually be able to take orders directly from consumers and cut out a whole layer of inefficiency.

Although the scale of car manufacturing means that companies use materials that are manifestly available, there will still be opportunities for substitution. For instance, carbon fiber will be used instead of steel because it is far stronger and lighter, allowing longer driving range and better acceleration. The new BMW i3 already incorporates a carbon fiber body, just like the Boeing 787 Dreamliner. Electric motors may substitute for the internal combustion engine in massive quantities.

While much of the material in cars is already recycled, the use of "circularity" – the idea that technology and materials continually cycle through the economy the way nutrients cycle through a biological system – promises greater gains. Systems or components can be upgraded, refurbished, reused, or materials reclaimed and recycled, leading to multiple uses, longer life, and much higher productivity, because the same amount of natural resource generates much more functional use in an efficient economy. For cars, circularity can mean higher recycling rates for steel and glass, as Lexus and Ford and others have achieved, but can also mean software upgrades that add capability to the car. Car companies may not be the ones to think about virtualization – they want cars to be used, not circumvented – but plenty of other companies will find ways to avoid having people climb into cars and drive places. Amazon, for instance, is trying to crack the code on grocery deliveries with Amazon Fresh pilots in Seattle and Los Angeles, obviating all those quick trips to the store. Amazon leverages customer optimization technology to increase the density of deliveries on routes and improve margins.

Then there's Google, which is trying to take the driver out of driving. Its car already has a license to operate in California, Florida, and Nevada (with a driver behind the wheel, ready to take over if needed). The car has driven more than 500,000 miles without causing an accident. Even if Google doesn't try to commercialize the technology – and a $258 million investment in Uber, the car-hailing app company, suggests that Google is serious – the company has created an arms race in driverless cars. Nissan has already said it will have driverless cars on the market by 2020; Tesla and Daimler have also committed, and the new Mercedes S-Class is already close to driving on its own.

The cars are improving fast. In 2008, a state-of-the-art driverless car went two blocks on a closed course at 25 mph; today, a car can operate in real-world conditions while traveling at 75 mph. Because electronics are the key to the driverless car, improvement is expected to continue at the pace of Moore's Law, which says that advances in digital devices will occur at exponential rates. In fact, improvement will accelerate as more cars get on the road. Unlike humans, who learn primarily from their own experiences, the artificial intelligence software in the Google car learns from every experience of every car. If hundreds of thousands or millions are on the roads, they will generate a real-time map of road conditions, so every car that needs to know will be made aware of an oil spill that just happened or that there is black ice on a road at a certain spot.

Through virtualization, the driverless car could increase productivity in all facets of car use. Far fewer cars would be needed, because they would stay in constant use rather than being parked 96 percent of the time.

In an example of optimization, self-driving cars would get better mileage, because they could "platoon" on highways, driving a few feet apart – if the first car had to slow or stop, it could signal the cars behind it and have them all hit the brakes simultaneously. Platooning increases gas mileage by 30 to 40 percent because every car except the one in the lead drafts behind the car ahead.

If the cars demonstrate that they can greatly reduce crashes – Google predicts that accidents will drop 90 percent – then many of the safety systems and much of the weight can be taken out of cars. Cars could also generally be smaller. At the moment, people tend to buy the biggest car that they might possibly need, say for soccer car pools, but the optimal driverless car can be summoned for each trip. Most trips are one- or two-person journeys, so far fewer large cars would be needed.

As is often the case with a breakthrough in resource productivity, the ripples from a successful driverless car would spread far and wide. The biggest benefit would be the human one. If Google is right that its car can reduce accidents by 90 percent, that would mean more than 30,000 lives would be saved in the United States every year. More than 2 million people, just in the United States, wouldn't have to go to emergency rooms because of traffic accidents; and $260 billion would be saved, according to an American Automobile Association study. People would also gain ten additional "days" per year – the time we now waste in traffic jams.

Fewer roads would need to be built, because cars would travel more closely together. Today, optimal capacity on a freeway is about forty to fifty cars per mile. Once you get to around 200 cars per mile, we call it a severe traffic jam; speeds drop to below 15 mph. If Google cars coordinated, we could fit 320 cars per lane per mile at highway speed. That's the equivalent of making a four-lane highway into a thirty-two-lane super freeway. We can stop building new roads. We will also be able to reclaim most parking lots; they could be used for building or turned into green space. Many self-driving cars would just head off to pick up another passenger.

There would, of course, be losers, too. Companies that build cars and build and service roads would see business plunge. Many car insurance companies would go out of business. Who needs liability insurance if there aren't any accidents? And how do you steal a self-driving car? Similarly, many body shops would go out of business; the primary repairs would be for things like hailstorms and foul balls from baseball games. Governments, which are already losing revenue as vehicle miles traveled decline and reduce the taxes paid on gasoline, would lose more revenue, because traffic fines would disappear – all cars would obey all laws; at the same time, governments would also need fewer police officers on the road and would need less jail space, if only because drunk drivers would no longer be an issue.

Rather than having millions of drivers acting on their own, cars could be managed as a network, a change that would create all sorts of opportunities for new businesses. For instance, a company might offer consumers transportation that they would pay for by the mile. Studies suggest that a company could offer a consumer access to car transportation for 80 percent less than he currently pays, and still make a hefty profit. Today, telecom companies make 8.5 percent net margins selling minutes, while automotive companies make about 4 percent selling cars. Why not make 15 percent selling miles? In addition, if someone can crack the code and provide a sort of operating system for driverless cars, that company could become the Microsoft or, in fact, the Google of the car business.

Even if the driverless car doesn't fulfill the big dreams that are being laid out for it, it shows how inexpensive innovation is these days. The Google car is the work of just a dozen engineers and cost Google some $50 million.