Automotive Research and Development

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Part I Industry Review

Introduction

It is estimated the average rate of return on capital investment in the United States today ranges from 10% to 14%. In contrast, the private rate of return of R&D investments is now estimated to be 25% to 30%. Furthermore, the social rate of return of R&D investments, that is the rate of return that accrues not just to one firm, but to many firms, industries, and consumers in the society, is typically 50% to 60%, almost four times the rate for other types of investment (NSB, 2004).

In the Triad regions (the United States of America and Canada, i.e. North America, Japan and Western Europe), the vehicles industry is mature and has been plagued by overcapacity, cost pressures and low profitability. Only North America was buoyant at the end of the 1990s out of the three Triad economies. This resulted from the long boom of the United States' economy, the substitution of imported Japanese cars by cars built in transplant factories, and the profitable shift of consumer demand from passenger cars towards light trucks. In contrast, vehicle sales in both Western Europe and Japan were less in 1997 than they had been in 1990. Overall, vehicle sales in the three Triad regions rose by only 0.6 per cent between 1990 and 1997, and production rose by 4.2% (Humphrey 2003).

Companies no longer make decisions to locate and expand in states based on tax policies and incentives alone. Rather decisions are based on a state's talent pool and culture for innovation, with particular focus on world-class research universities (Duderstadt 2005). In the past, the facilities of foreign automotive companies, while nominally involved in R&D, did little or nothing of this nature. Instead, their main activities were, first, testing emissions for certification requirements and scanning the general regulatory environment; second, evaluating the performance of their own and competitors' vehicles; and, third, monitoring US. automotive design and styling trends. Recently, however, more ambitious aims have emerged. Several of the current facilities have embraced advanced concept design, joint research, and vehicle prototype production. In addition, companies have started research in parts and materials design and evaluation, research on key technologies (such as new materials and battery technology), and the development of parts suppliers locally.

The necessity of having R&D facilities in North America became evident in the early 1990's.

> Prior to establishing an R&D center in [the United States], our engineers in [the US. Plant] had to work with the R&D division and technical centers in Japan. We were sending faxes to each other all the time and our engineers took many trips between Japan and the United States. The process of developing and producing a car for the US. market or correcting an engineering problem was very time consuming. We have eliminated this lengthy process by establishing a U.S. technical center [in close proximity] to our U.S. plant, sales office, and suppliers in the United States. We expect to shorten the time needed for concurrent design and development, concurrent development and engineering, and working on design and engineering issues for our vehicles in or near production. (Manuel, Dalton 1994)

These advanced facilities created opportunities within the US for high-tech automotive jobs and business growth.

Auto R&D Definition

Automotive research and development refers to any facility that supports at least one of the following activities.

1. Technical support for procurement of parts for local production
2. Evaluations of parts
3. Evaluation of vehicles
4. Styling and general design

5. Parts design
6. Vehicle design
7. Prototype production

Global Auto Industry

Recently, three significant changes have taken place in the automotive industry's value chain. First, there has been a shift in design activities from assemblers to suppliers, alongside increased dialogue around design between the two parties. The suppliers, who had previously provided ready-designed parts (for example, batteries) for many different companies in the period of mass production, moved towards greater customization, tailoring their products to the needs of specific companies. Similarly, many of the subcontracting companies that had formerly worked to the assemblers' designs moved towards offering their own design solutions. In both cases, the assembler provides the overall performance specifications and information about the interface with the rest of the car, and the supplier then designs a solution using its own technology.

Second, there has been a shift towards the supply of complete functions (systems, sub-assemblies or modules) rather than individual components. A first-tier supplier becomes responsible not only for the assembly of parts into complete units (dashboards, brake-axle-suspension, seats, cockpit assemblies and soon), but also for the management of second-tier suppliers. The assembler would previously have put these modules or systems in-house, using parts supplied by many different component companies. In the past, an assembler might design a seat, make detailed drawings of 20-30 separate elements, find suppliers for each, take in the parts and assemble them into seats in-house. Currently, the assemblers look for firms that will design and supply the whole seat, or even a seating system, including headrest, seat belts and pretensioners. This has become part of the process of the increasing outsourcing to suppliers.

Third, the assemblers has become more involved in the specification of the production and quality systems of their suppliers. With the increasing importance of just-in-time (JIT) production systems and the imposition of quality-at-source, even simple tasks became more critical for the overall efficiency of the operations. The assembler had to invest in its relationships with suppliers. Accordingly, it made sense to have longer-term relationships with fewer suppliers (Appendix I: Figure 1).

The global auto industry at the beginning of the 21st century is composed of a number of different parts. The requirements of these different sections are quite distinct. Assemblers and global mega-suppliers need global reach, innovation and design capabilities, as well as considerable financial resources. In the second tier, global reach is not required, even though there are some tendencies towards internationalization in this sector. The competences needed in the third-tier are much less, but the returns are much lower. Finally, the aftermarket section offers a completely different route to customers. The business is much more fragmented and access is easier, but this sector is very price-competitive (Humphrey 2003).

Assemblers are characterized by an increasing requirement to spread the costs of vehicle design and branding. Innovation and design capabilities remain critical as first movers in new markets sections can gain important rents while other companies follow. Some companies, such as Ford, appear to believe that core competences lie more in branding and finance, and they are outsourcing parts of manufacturing. Others, such as Toyota, maintain an emphasis on manufacturing excellence and competence.

Global mega-suppliers are firms that supply major systems to the assemblers. They are sometimes referred to as "Tier 0.5" suppliers, because they are closer to the assemblers than the first-tier suppliers. These companies must have global coverage in order to follow their customers to various locations around the world. They need design and innovation capabilities in order to provide black-box solutions for the requirements of their customers. Black-box solutions are solutions created by the suppliers using their own technology to meet the performance and interface requirements set by assemblers.

First-tier suppliers are firms that supply direct to the assemblers. Some of these suppliers have evolved into global mega-suppliers. First-tier suppliers require design and innovation capabilities, but their global reach may be more limited. Second-tier suppliers are firms that will often work to designs provided by assemblers or global megasuppliers. They require process-engineering skills in order to meet cost and flexibility requirements. In addition, the ability to meet quality requirements and obtain ISO9000 and increasingly QS9000 (Appendix I: Figure 2) quality certification is essential for remaining in the market. These firms may supply just one market, but there is some evidence of increasing internationalization.

Third-tier suppliers supply basic products. In most cases, only rudimentary engineering skills are required. In the third-tier of the component chain, skill levels and investments in training were limited and firms compete predominantly on price. A further important segment of the automotive value chain is the aftermarket for replacement parts. This is the sector that many firms in developing countries first moved into, even before local assembly sectors were developed. Presently, there is an international trade in aftermarket products. Firms in this section compete predominantly on price and access to cheaper raw materials and process engineering skills is important. Innovation is not required because designs are copied from the existing components, but reverse engineering capability and competence to translate designs into detailed drawings are important.

Auto R&D Value Chain

When a design team has been given the green light to start the development of a new component, the associated activities and processes can be analyzed in three stages: planning, design, and production. The planning phase activities refer to the functional specifications in the new product such as general product definition, lead time requirements, definition of interface specifications, platform/architecture design specifications, and outsourcing decisions. The design and production stages are often referred to as detailed engineering phase where bill of materials and blue prints are generated, prototypes are built and tested, manufacturing processes and equipment are selected and qualified (Appendix I: Figure 3).

Essentially, a system producer faces three alternatives to manage the development of new components: in-house sourcing, outsourcing, or co-development. In co-development the supplier and buyer join forces to set industry standards or create new innovation. Co-development is justified when technologies are so expensive that individual firms cannot afford to develop them alone. In many cases, firms join forces to create the technological synergy necessary for innovation. Outsourced components can be classified as detail-controlled parts, supplier proprietary parts, or black-box parts.

Detailed control parts are developed entirely by assemblers including functional specification and detailed engineering. Specialized suppliers are selected through inquiries and bids to take the responsibility for process engineering and production based on blueprints provided by assemblers. Detailed-controlled parts are advantageous when an assembler wants to preserve detailed technological capabilities in a particular component area, tightly control component design quality and preserve bargaining power with respect to supplier parts prices. With detail-controlled components, the assembler is dependent on the supplier to deliver the part built to exact specifications. After supplier selection from the bidding process, the assembler gets involved with supplier's manufacturing, purchasing, and distribution practices (Appendix I: Figure 4).

Supplier proprietary parts are developed entirely by parts supplier including functional specification and detailed engineering. These parts are taken by the supplier from concept to production and sold to assemblers through catalogue. Often the assembler becomes dependent on supplier for availability, upgrades, and system integration. The supplier of these parts often shows dominance over the technological path of innovation in question. In addition, these components often have well-specified and standardized interfaces and supplier performance can be contracted ex ante.

Black-box parts are those parts whose functional specifications is completed by assemblers while detailed engineering is carried out by parts suppliers. The development work of black-box parts is split between the assembler and the supplier. Typically, assembler's responsibilities include generation of cost/performance requirements, exterior shapes, interface details, and other basic design information based on total vehicle planning and layout. Black-box parts enable assemblers to utilize supplier's engineering expertise and manpower while maintaining control of basic design and total system integrity. To the supplier, the accumulation of engineering expertise becomes its competitive edge. Prototypes and production parts exchange between the supplier and the assembler. Added value can be attained when supplier and assembler are willing to collaborate in solving technical problems, especially in resolving interface compatibility issues when new technological solutions are created and patents attained (Appendix I: Figure 5).

Government Automotive Policy

Based on the current understanding of what successfully drives and guides the process of technical change, the role of government policy has shifted from pure supply-push, such as government funded R&D, and become more focused on the demand side and the utilization of scientific discoveries in society.

Lessons from Hydrogen Technology

Almost all the major car companies in the US, Europe and Japan have active programs to develop hydrogen vehicles. Overall private spending on hydrogen energy R&D dwarfs spending by governments, however standards are set by government agencies. Therefore, gpvernment directs the paths of investment. Most of the car company prototype hydrogen vehicles require use of fuel cells. It is difficult to determine which automaker will win the race to commercialization and affordability. BMW was a pioneer and has had prototype hydrogen cars since the 1960s. Honda and Toyota first leased a few hydrogen-powered Fuel Cell Vehicles (FCVs) in California in December 2002, and hope to be the first entrants (along with BMW and Nissan) into the lucrative US retail market. Other car companies followed suit with new leasing arrangements in 2004.

Japan

Japan is one of the most important players in the international effort to develop a hydrogen economy, not merely in R&D but also in terms of production plans. Several factors are responsible for Japan's leadership role: the government's commitment to the Kyoto Protocol, the country's high dependence on imported petroleum for transportation, and Japan's need to retain its position as the high-tech superpower for new technologies both for its image and its economy.

The WE-NET (World Energy Network) project was initiated in 1993 to enable the introduction of a worldwide network for development of abundant renewable energy resources, their transportation and utilization. The WE-NET project, completed in 2002, was a large government–academia–industry joint venture coordinated by the New Energy and Industrial Technology Development Organization, which acted as the chief vehicle for planning and implementation of hydrogen related R&D (WE-NET, 2004). Phase I of the WE-NET project lasted from 1993–98 and focused on research on the feasibility of different hydrogen technologies, and planning a vision for Japan's hydrogen energy network. Phase II of the WE-NET project lasted from 1999–2002 and focused on introduction, demonstration and testing of selected hydrogen technologies and infrastructure as well as further research and planning. The combined R&D budget for the first two phases was 20 billion yen (nearly US $200 million). A follow-up project called the Development of Fundamental Technologies in the Safe Utilization of Hydrogen is envisioned to last until 2020 and focus on the gradual diffusion and penetration of the hydrogen energy infrastructure in Japan.

The WE-NET project has developed detailed plans for all the different components of the hydrogen energy network including production, storage, transport and utilization. In the near term most of the hydrogen is expected to come from reforming of fossil fuel based sources with electrolysis, particularly from renewable generated electricity, becoming the major mode of production in the long term. Liquefaction has been seen as the main method for large-scale hydrogen storage and transportation, and the WE-NET project has been extensively researching liquefaction plants and liquefied hydrogen tankers. Development of a hydrogen combustion turbine is another important area of R&D for WE-NET, and a pilot plant with an expected 60% efficiency will be developed for testing.

The area where progress and publicity has been most evident has been FCVs and related infrastructure. Several dozen FCVs made by Japanese (Toyota, Honda, etc.) as well as international (GM, DaimlerChrysler) automakers are currently in service in various public and commercial fleets in Japan, starting with a handful in 2001. The Japan Hydrogen and Fuel Cell Demonstration Project (JHFC) was launched in 2002 by the Ministry of Economy, Trade and Industry in partnership with all major automakers, Japanese utilities and energy companies. The JHFC project has also started testing fuel-cell cars and buses under a variety of real-life conditions to gather data on performance, reliability and fuel consumption for evaluation. The WE-NET project estimates that in the near term methanol or gasoline reforming would be the most practicable technology for fuel cell applications but has a long-term goal of adopting pure hydrogen.

The MITI is responsible for Japanese industrial policy and strategic legislation that affects industry and therefore it is responsible for Japanese energy policy, R&D policy and technology policy. The responsibility of the MITI in the transport sector has foremost been to support the development of new vehicles and fuels. The MITI may fund company research on technologies that are in the public interest with 100% funding at the early stage of development and between 50 to 67% as the technology comes closer to commercialization. Standardization projects receive 100% funding from the MITI (Ahman 2004). The MITI has identified three areas in which government support is needed in equal measures: R&D on methods for providing hydrogen, standardization, and fuels and infrastructure.

The Japanese Government regards fuel cell development for vehicle use as a strategic issue for the nation in the long term. Today, most Japanese automobile manufacturers regard the fuel cell system as a strategic and proprietary issue and development is pursued in-house or together with other private companies. An important finding from previous efforts to establish BPEV charging stations is the need for early standardization. Standardization is also seen as strategically important for Japan; not letting other countries to set the standards, but influencing coming world standards in a Japanese way.

European Union

While Germany has the most advanced hydrogen energy program in continental Europe, the most important regional policy initiative is that of the European Union (EU) and European Commission (EC). A major report and action plan were issued by the EU/EC in 2003 that outline the hydrogen vision. The report is a significant indication of the EC's commitment to a long-term conversion to a hydrogen economy—the first major political body to do so beyond Iceland and Japan. A High-Level Group (HLG) was put together to examine the potential contribution that hydrogen and fuel cells can play in the long run to achieving viable, sustainable energy systems for Western Europe. The HLG was created in 2002 by the Vice President of the EC responsible for energy and transport, and the Research Commissioner. It consists of representatives from some of Europe's leading energy, automobile, and research institutions, i.e., “stakeholders.” The report suggests that traditional fossil fuels and nuclear power can be used to produce hydrogen energy, along with renewable energy sources, though with carbon sequestration in the case of the former feedstocks.

The report recommends the creation of a European Hydrogen and Fuel Cell Technology Partnership, to be steered by an Advisory Council. An important local hydrogen partnership was established in London in 2002. It also suggests drafting of a Strategic Research Agenda and a Roadmap to define research priorities, for planning, to set technical targets, and to outline pathways for the development of European hydrogen and fuel-cell technologies. The driving forces behind these recommendations are both to secure a sustainable energy future (and to not contribute to global climate change). In addition the initiative is designed to secure diverse energy sources and avoid over-reliance on Middle Eastern oil imports.

The draft EC report suggested that fuel cells are intrinsically cleaner and more efficient that conventional energy converters. The main problem with this is the focus on the cleanliness of the energy carrier instead of the cleanliness of the fuel used to make that carrier. Several existing hydrogen and fuel cell initiatives in EU member states were highlighted, such as the testing of 30 Mercedes-Benz, fuel-cell busses since 2003 in 10 major European cities. These cities include London, Hamburg, Madrid, Barcelona and Stockholm. In addition, the report also calls for the establishment of several “centers of excellence” for critical research, to develop rules on intellectual property rights, etc. The government financial support anticipated for hydrogen and fuel-cell development in the EC would be boosted to $2 billion over four years, as compared to US DOE support of $1.7 billion over 5 years. The report ends with a call for strong public subsidy, since at the present time the hydrogen/fuel-cell conversion cannot compete with conventional fuel combustion technologies.

The lack of stronger renewable-based hydrogen policies in Europe is surprising, given the strong commitment to wind and (to a lesser extent) solar energy production in Germany, Spain and Denmark. There are also major hydrogen and renewable energy initiatives in the UK, though these are at an early stage. Finally, several of the initial hydrogen energy fueling stations in Western Europe are based on renewable energy sources for the hydrogen, such as hydroelectricity, geothermal, solar photovoltaic and wind power (Solomon 2004).

DaimlerChrysler is expanding its on-road fleet to 20–37 FCVs in 2004 in the US and another 60–70 in Europe and East Asia. These vehicles include cars, city busses, and a sprinter van based on compressed-gaseous hydrogen converted from methanol. The automaker already has spent $1 billion to develop and demonstrate successive generations of its New Electric Car (NECAR), first introduced in 1994, and plans to spend $1 billion more over the next 5–10 years. The NECAR-5 completed a cross-country journey to Washington, DC in 2002. DaimlerChrysler initially had hoped to produce and sell 100,000 of these vehicles by 2010 although 2015–25 is now more realistic (Ahman 2004).

United States

The larger exporting automobile manufacturers saw the future BPEV market in California as both strategically and economically important. Toyota, Nissan and Honda were all affected by the Californian ZEV mandate and now entered the BPEV development race more seriously than before and began investing heavily in BPEV technology. Seizing an opportunity for leadership on new energy and automotive technology, however, several state governments have developed their own hydrogen energy programs. Chief among these are California, Michigan, Ohio and Hawaii.

The California Fuel Cell Partnership, based in Sacramento, is a public-private venture that began in April 1999 and includes auto manufacturers, energy providers, fuel-cell companies, and State and Federal government agencies. Its goals are to demonstrate hydrogen FCV technology and alternative fuel infrastructure and fueling stations, explore the path to commercialization and increase public awareness. The Fuel Cell Partnership was stimulated in part by the California Air Resources Board's original mandate that 10% of new cars sold in the State by 2003 were to be Zero Emission Vehicles. This deadline has since been modified and delayed because of three lawsuits filed by GM, DaimlerChrysler and Isuzu. Nevertheless, thus far California can point to several public demonstrations of hydrogen vehicles and by far the most hydrogen fueling stations in the US. The California Partnership plans to place up to 300 fuel-cell cars and busses in fleets over the next few years, especially in the Los Angeles and San Francisco-Sacramento metro regions (Banerjee 2004).

The State of Michigan’s program is called the “NextEnergy” plan, in April 2002. Michigan's effort is similar to that of California, and includes a NextEnergy Zone in Detroit designated as a Renaissance Zone (a tax-free area that could result in tax rebates based on job creation) in the hopes of luring cutting-edge, hydrogen R&D companies from around the world. Further tax breaks would be available to individuals and institutions that purchase the hydrogen-energy technologies created in the State. This program is expected to cost $50 million over 3–5 years. The Michigan announcement was followed by a competing $100 million, three year hydrogen fuel cell initiative in Ohio (Bodipo-Memba, 2002). A smaller program was established in 2000 in Hawaii (Dunn, 2001). While the goal of Hawaii's program is to develop hydrogen fuel for use in the State and for export based on solar, wind and geothermal energies and perhaps methane hydrates, the Michigan and Ohio programs will more likely be based on fossil fuels.

GM plans to mass produce a fuel-cell car called the AUTOnomy with a range of 200 miles. Since this prototype vehicle will have few parts its production cost is expected to be low. GM's initial goal was to sell 1 million, affordable AUTOnomy's worldwide by 2010, although again 2015–25 is more realistic. GM is working with Dow Chemical Co. to demonstrate and reduce the cost of its fuel-cell technology at Dow's Freeport chemical plant in Texas. The third major US carmaker, Ford, plans to test 30 hybridized fuel-cell cars (specifically an option on its Ford Focus) in Sacramento, Detroit and Orlando in late 2004. BP and Ballard are supporting this initiative. Embedded in these market plans are alternate assumptions about the need for and cost of a hydrogen fuel delivery infrastructure vs. small steam gas or methane reformers, or electrolyzers at local fueling stations. As of today, however, hydrogen cars are far from affordable and far from a cost-effective option to lower air pollution, greenhouse gases, or to improve energy security (Solomon 2004).

Michigan

The high-tech sector is large in total in Michigan, with almost a quarter of a million workers in 2004–05. Over half of them are in industrial high tech, many associated with advanced manufacturing in the auto industry. Michigan is one of the national leaders in industrial high tech (Appendix II: Figure 1). The sector grew very rapidly during the 1990s, but has turned down with the rest of the economy since 2000. A similar analysis of U.S. Patent Office information on patents received by state found that Michigan ranked in sixth position with 17,603 patents received during the five-year period 1997-2001 (Appendix II: Figure 2).

One industry trade publication in mid-90's, located 74 of 81 known U.S. automotive supplier R&D facilities in Michigan. The Michigan facilities accounted for all but 270 of the 11,966 (98%) jobs listed in these 81 supplier R&D facilities. Michigan had all 23 of the listed foreign-owned supplier facilities. These new foreign supplier facilities have all been built in the last seven years and now employ over 2,100. In recent years, the state has also seen the startup of new vehicle producer R&D facilities by such companies as Nissan, Mazda, Toyota and Saturn. In addition to R&D from the traditional automotive companies, Michigan houses over 215 automotive research centers. For example, the Michigan Technology Tri-Corridor, focuses on R&D and commercialization in the fields of life sciences, advanced automotive technology, and homeland security (Duderstadt 2004).

Michigan's advantage in industrial high-tech reflects the fact that it is the "capital" of the U.S. auto industry. Because the Big Three are headquartered in Michigan, their research, engineering, and design functions are also centered here. In addition, many overseas auto producers have located their U.S. tech centers in Michigan, and are currently expanding these operations. This results in a massive investment in technology resources in Michigan and the creation of a large technology-related employment base (Fulton, Grimes 2006).

The TTC in Ann Arbor, MI contains 106 acres of land and 559,000 sq. ft. of floor space. The TTC facilities include an Engineering Design building, an Evaluation building, an Administration building, an Emission & Engine Tuning Lab, a Prototype Lab, and a Check Road. The Ann Arbor facilities employ 583 workers, by far the majority of Toyotas North America R&D 728 employees.

The Toyota Tech Center (TTC), conducts automotive R&D work in technical support for procurement of parts for local production, evaluations of parts, evaluation of vehicles, styling, general design, emissions certification and technical research. TTC is also playing an increasingly important role in the design-engineering and development of Toyota products, particularly those developed for the North American market. Major vehicle developments include:

- 1994 Camry Coupe Launched
- 1995 Avalon Launched
- 1997 Camry Sedan Launched
- 2000 Avalon Launched
- 2002 Camry Sedan Launched
- 2004 Sienna Launched
- 2004 Solara Launched

The company's mission for the future is to continue to support Toyota's reputation for excellence by developing automotive parts and materials that represent the best in quality, cost, function and timing. In addition, TTC strives to contribute to the quality-of-life and economic growth of the communities it serves, and to promote stable employment and the well-being of its employees. In mid-2005 Toyota announced it had signed a purchase agreement with the State of Michigan for property being offered by the State of Michigan. The approximately 690 parcel of land owned by the State of Michigan is located at the North West corner of US 23 and Willis Road in York Township, Michigan. TTC plans to expand its research and development operations to complement Toyota's increased localization and growth of manufacturing and sales in North America. TTC's current 106 acre Ann Arbor campus has limited space for future growth.

Dr. Akihiko Saito, Executive Vice President, Toyota Motor Corporation said of the new aquisition:

> We think the York Township property is large enough to give us the assurance of being able to plan for TTC's short term as well as long term growth," said. "The North American growth in sales opened the door for Toyota to establish our manufacturing operations which in turn supported the localization of our R&D presence. The York Township property will provide adequate space to conduct our engineering and research for Toyota's core North American vehicle development programs (toyota.com).

The purchase agreement allows TTC to move forward with due diligence activities and obtain various approvals, which include zoning changes and site plan approval by York Township. The first development phase is targeted for a capital investment of $150 million and will add 400 new jobs by 2010. In addition, "The State of Michigan has been very active throughout this process and we appreciate the strong support. We believe Michigan is the optimum place for Toyota to expand its home base for North American engineering, development and research operations," said Mr. Yasuhiko Ichihashi, President of Toyota Technical Center, USA Inc. (toyota.com).

Honda has one office in Michigan called the Honda R&D Americas. The HRA Detroit office is located in Southfield Michigan, a suburb Northwest of Detroit. The overall purpose of the Automobile Technology Research (ATR) Group is performing research that will help us better meet the future needs of Honda's customers. They are investigating two main areas: the first is precompetitive cooperative research with other Automakers, the US Government and Universities on advanced automotive safety, the second is identifying and researching future technology areas (honda.com).

In addition, the Nissan Technical Center North America, Inc. is in Farmington Hills, MI with 250 employees in technical support for procurement of parts for local production, evaluations of parts, evaluation of vehicles, styling and general design, parts design vehicle design and prototype production (nissan.com).Isuzu Motors America, Inc. has an office in Detroit that employs around 100 individuals in technical support for procurement of parts for local production, evaluations of parts, and evaluation of vehicles (isuzu.com).

Two of Mazda North American Operations Inc. are situated in Flat Rock, MI and Ann Arbor, MI employing 63 individuals in positions regarding technical support for procurement of parts for local production, evaluations of parts, evaluation of vehicles, styling and general design, parts design vehicle design and prototype production. Mitsubishi Motors R&D of America, Inc. has an operation in Ann Arbor, MI. The facility support roughly 50 jobs and these jobs are in technical support for procurement of parts for local production, evaluations of parts, evaluation of vehicles, styling and general design, parts design vehicle design and prototype production (mazda.com).

GM Research is housed in a 10-building complex at the General Motors Technical Center, located in southeast Michigan. The center was first opened in the early 1950s and is currently undergoing a major renovation that includes a world-class computer network, state-of-the-art engineering facilities, and a new climatic wind tunnel. The R&D Center also is the home of the GM Library and Information Centers, which access global databases and library holdings around the world. The Research staff of 650 reflects GM global emphasis. The R&D Center draws on talent from around the world. More than 50 percent of the staff are professional researchers, and more than 85 percent of those have PhDs. Not surprisingly, the Big 10 universities are well-represented among the staff, but so are the Massachusetts Institute of Technology, the University of California at Berkeley, and the universities of England. Fields of study also run the gamut, from Electrical Engineering to Chemistry to Engineering Mechanics.

Ford Motor Company's Scientific Research Laboratory, in Dearborn, MI has been in operation since 1951. The lab has made significant contributions to the auto industry and society, developing cleaner, safer and more fuel-efficient vehicles. This research will continue under the leadership of Dr. Gerhard Schmidt, who assumed the position of vice president-Research at Ford Motor Company in 2001. He joined Ford from BMW AG, where he led powertrain development. Schmidt leads a team of more than 1,000 scientists, engineers and technicians from over 50 countries whose collaborative work is a model for diversity.

The motor-vehicle industry’s high level of R&D spending naturally influences Michigan’s position in a similar ranking of states. Michigan ranked second among the fifty states in total private spending on R&D at $17.7 billion in 1999 (Appendix: II Figure 3). The Office for the Study of Automotive Transportation, (now CAR) conducted a special survey (fall of 1999) of the three largest motorvehicle-manufacturing firms in the United States (General Motors, Ford, and DaimlerChrysler) to directly tabulate their high-tech employment. The three automotive firms were asked to provide their year-end, 1998, U.S. and Michigan employment in the list of technology-oriented occupations. Technology-oriented U.S. employment for the three firms totaled 47,548 in 1998. The Big Three employed 37,489 of these employees in Michigan. In other words, almost 79 percent of Big Three, U.S., technology-oriented employees were working in the State of Michigan in 1998. Furthermore, the results show that about 16 percent of the three companies' employment in Michigan falls into the high-tech category compared with only 4 percent of their employment in the other 49 states (Appendix II: Figures 4 & 5).

Many experts believe that Michigan continues to hold a number of advantages as a predominant site for automotive R&D. These include the presence of the Big Three product development operations and the National Emissions Testing Laboratory of the Environmental Protection Agency (EPA) in Ann Arbor. More importantly, perhaps, is the fact that southeast Michigan contains the largest known concentration of experienced automotive engineering talent (and active members of the Society of Automotive Engineers) in the world. Automotive engineers, it is believed, are almost exclusively trained within motor vehicle firms and a handful of large suppliers. This critical source of automotive R&D labor actually attracts new automotive R&D operations to the state. For example, Nissan's Director of North American R&D was quoted in Automotive News as saying that, "Michigan is a logical choice. . .it is fashionable to have studios in California, but future product development is moving to Detroit" (Feinstein 2000).

This is a reality which, of course, only reinforces the decision of many automotive engineers to remain in Michigan, in close proximity to the largest and most active labor market, for their services. The state's university system has reinforced this concentration to some extent by maintaining a number of automotive R&D programs in their engineering and institute programs alongside graduating the third most engineering students in the country (Appendix II: Figure 6). In addition, because of the growing interdependence between the auto manufacturers and their supplier firms many suppliers have located their technology-intensive operations in Michigan. In other words, Michigan's automotive industry is far more technology intensive than the U.S. automotive industry in general and this is reflected in Michigan being the number one state in industrial R&D intensity (Feinstein 2000). Overall, Michigan is the number one state for vehicle-related R&D activity, spending $10.3 billion annually and employing over 65,000 professionals statewide (Appendix II: Figure 7).

California

Automotive companies, both U.S. and non- U.S., have chosen the Los Angeles Metropolitan Area and other parts of Southern California as the place to put design studios. There are 13 such studios in Southern California, seven being Japanese, three being American, and the other three being Swedish, German, and South Korean (Manuel, Dalton 1994). Calty Design Research, Inc. was the first major R&D institution established by a foreign auto firm in the US.

The Calty Design Research, Inc. in Newport Beach, California contains 8.4 acres of land and 72,500 sq. ft. of floor space. Included in these facilities is an Emission Lab & Engine Tuning Lab, a Fuel Cell Partnership Lab, and a Satellite Research Laboratory. These facilities employs 107 of Toyotas 728 automotive R&D workers in the US. In addition, the lead involvement by Toyota's US.-based Calty Research Design in the exterior design of the Lexus/Soarer Coupe began a general movement toward higher-value-added activities in the US automotive industry by Toyota.

Honda Performance Development (HPD) located in Mountview, California engages in technical support for procurement of parts for local production, evaluations of parts, evaluation of vehicles, styling and general design, parts design, vehicle design and prototype production occur at these facilities. The facility is located 30 miles north of Los Angeles, HPD, a subsidiary of American Honda Motor Co., Inc., is the technical operations center for Honda's North American motorsports engine programs. Currently, HPD is focused on American Honda's participation in the IRL IndyCar Series and the R&D of the Honda Indy V8 racing engine. Established in April of 1993, HPD currently operates out of a recently renovated 123,000-square-foot building in Santa Clarita. This two-story structure houses comprehensive engine design, engineering development, preparation, rebuilding and inspection areas, transit-style dynamometer test cells, machine shop, parts center and administrative support facilities.

In addition, Honda has an Honda R&D Americas facility in Los Angeles. The Los Angeles Center has the responsibility of envisioning the products customers will want tomorrow. The focus is on product planning, market research, styling design and engineering research. In addition, the LA associates strive to balance the needs of the individual with environmental and safety concerns. The Los Angeles Center has evolved from an emphasis on concept cars to the design of mass production vehicles manufactured at Honda's production facilities in the U.S. and Canada.

The Honda Proving Center California is within two hours of Los Angeles International Airport, Honda R&D Americas Inc. in LA, and American Honda Motor

Company, Inc. in Torrance. This site offers a unique variety of environments for vehicle evaluation including on-site paved test courses modeled after common North American public roads.

One of Nissan Design International, Inc's facilities is located in San Diego and has 50 employees for designing only. In addition, Isuzu Motors America, Inc. in Los Angeles combined 192 employees including technical support for procurement of parts for local production, evaluations of parts, and evaluation of vehicles (isuzu.com).

Mazda North American Operations Inc. is situated in Irvine, CA; employing 40 individuals in positions regarding technical support for procurement of parts for local production, evaluations of parts, evaluation of vehicles, styling and general design, parts design vehicle design and prototype production. Mitsubishi Motors R&D of America, Inc. has an operation in Cypress, CA. The facility supports 63 jobs and these jobs are in technical support for procurement of parts for local production, evaluations of parts, evaluation of vehicles, styling and general design, parts design vehicle design and prototype production (mazda.com).

The DaimlerChrysler Research, Engineering and Design North America Inc. (DCREDNA) has three locations along the northern West Coast of the United States, each with a unique strategic mission closely linked to the business communities of those areas. DCREDNA in Palo Alto, in Silicon Valley, is the headquarters of DCREDNA. Its mission is to build on the innovative scientific community, technology and business environment of Silicon Valley to have a positive impact on DaimlerChrysler products, services and processes. DCREDNA is a member of The California Fuel Cell Partnership, in West Sacramento, CA. The DCREDNA Sacramento serves as a testing ground to advance fuel cell technology in DaimlerChrysler vehicles, both in North America and worldwide.

California is very competitive in most high-tech related areas and the automotive industry is one of them. Over all, California ranks first in R&D spending, first in the number of high-tech jobs, first in producing engineering students and second in automotive R&D spending. Many of these high numbers can be attributed to the sheer sizes of California's population but other factors must also be considered. For example, California succeeded in the high-tech sector even with an unfavorable tax regime. In addition, favorable government policies are in place towards education and research.

California's largest strength lies in its forward looking policies. California has been the nation trend setter for eco-friendly products and the automotive industry is no exception. The example of the hydrogen car is just one instance of California pushing the envelope in research initiatives. By setting standards for vehicle quality and emissions, California is placing itself at the forefront for increased R&D investment. In addition, the size of the California market is considerable and foreign companies need to be able to respond to trends in the industry by establishing R&D centers within the state.

Part II Policy Review

Introduction

Advanced automotive research and development policy is not very well articulated in the United States because it is a sub segment of an industry that has remained largely self-governed over its history. There are few policies that directly target this industrial segment and therefore few regulations. Nevertheless, policies do exist in both Michigan and California that target business growth in general and these policies and regulations do have an indirect impact on the current and future strength of the industry in both states.

Current Policies and Regulations: Michigan

The advanced automotive industry in Michigan is a thriving sector in our state's economy. Over $10.3 billion automotive R&D dollars are spent annually in Michigan employing over 60,000 professionals across the public and private sector. In this environment of economic success, the State of Michigan has chosen to implement very few policies and virtually no regulatory requirements on the sector. Outside of basic labor and environmental regulations that are applied across all sectors, the advanced automotive work done in Michigan is completed without state supervision.

Still, encouraging the proliferation of advanced automotive companies is one of the cornerstones to Governor Jennifer Granholm's economic development strategy. In August of 2004, the Governor unveiled the Michigan Automotive Industry Economic Development Strategy. While the plan has seven points, it can really be boiled down to two main action items: (1) to bring new business to Michigan from other states or countries, and (2) to help companies already in Michigan develop successful business models (MEDC – AA Business Strategy).

Governor Granholm never missed an opportunity to remind voters in the fall of 2006 that she would go anywhere and do anything to bring jobs to Michigan. Among her trips were fruitful missions to Japan and Germany that produced advanced automotive plants from companies such as Toyota and Daimler-Chrysler. The Governor has been successful in attracting investment in automotive R&D to this state partially through specifically tailored tax incentive programs and partially through the Small Business

Innovative Research (SBIR) /Small Business Technology Transfer (STTR) funds, which were made available through the 21st Century Jobs Fund. Unfortunately, these funds have been exhausted and no new grants are being issued at this time (SBA).

The 21st Century Jobs Fund has been specifically tailored to only a handful of Michigan industries, advanced automotive being one of them. In 2006, 26 advanced automotive proposals were funded for a total of $37.3 million of investment by the Michigan Strategic Economic Investment and Commercialization Board. Of the four Michigan industries the SEIC targeted, none had more projects funded and only one, life sciences, had more money invested in it. The SEIC is scheduled to award $75 million in new investment annually through 2015.

Ann Arbor's Spark, the administrator of the Ann Arbor Smartzone, has created their own statewide pre-seed capital fund with $8 million leveraged from the 21st Century Jobs Fund. This fund may be used to invest in companies in the life sciences, homeland security, alternative energy, as well as the advanced automotive industries. However, at the time of this writing only three companies have received support from the fund, two of which are in life sciences with the remaining in homeland security.

Current Policies and Regulations: California

California does not have any specific measures designed to retain or attract companies in automotive research and development. However, the state has various policies that promote the growth of business in general. Most recently, Governor Arnold Schwarzenegger, veto of Senate Bill 815, which prevented the changing off the historic workers' compensation reforms of 2004. By vetoing the bill the Governor also told small-business owners that it is safe to expand their enterprises and hire more people by preventing increases workers' compensation premiums that forced layoffs and business closures. In addition, Californians in 2004 approved Propositions 57 and 58, ballot measures that limit state spending and refinance the state's debt. That same year the Legislature passed the comprehensive workers' compensation reform bill (SB 899), reducing employer costs by billions of dollars.

Outside of the policy realm California has a multitude of reasons for investing advanced automotive work in the state. California has easy accessible information on starting and moving businesses to the state. The two most noticeable publications are the *Small Business Start-up Kit for California* and the *California Investment Guide: An Overview of Advantages, Assistance, Taxes and Permits*. These publications give a well laid vision for creating a business in the state as well as moving a business to the state, giving many reasons for doing so along the way. Regarding automotive research and development California offers:

- Over 2.5 million students are enrolled in 250 colleges and universities.
- The nation's highest concentration of engineers, scientists, mathematicians and skilled technicians.
- Six of the top 20 engineering schools are in California.
- California workers on average perform at 15% greater productivity than the national average (according to Alan Greenspan).
- In 2004, California companies received more than $9.3 billion or 45 percent of all venture capital dollars invested in the U.S.
- California offers a 15% R&D tax credit for in-house research and 24% for contract research, the highest in the nation.
- California is the #1 state in the nation for attracting foreign direct investment, reaching over $120 billion.
- California is globally connected with world-class infrastructure. More than 15,000 miles of highways and freeways carry over 1.3 billion tons of freight per year. Twelve cargo airports carry more than 3 million tons of freight per year. Eleven cargo seaports handle more than 7.7 million TEU's (containers) and 60 million metric tons per year of shipments, over 1/3 of the nation's total waterborne cargo.
- Eighteen foreign trade zones (FTZ) allow tenants to delay or forgo import and export duties on goods and raw materials until they enter U.S. commerce.

- Twenty-nine freight railroads operate over nearly 6,000 miles carry over 6 million carloads and 155 million tons of freight

The most import provision out of this list for advanced automotive is the research tax credit. It was designed to encourage companies to increase their basic research and development activities in California, the research and development tax credit allows companies to receive a 15 percent credit against their bank and corporation tax liability for qualified in-house research expenses, and a 24 percent credit for basic research payments to outside organizations. Qualified research expenses generally include wages, supplies and contract research costs. To qualify, research must be conducted within California and include basic or applied research of scientific inquiry, original investigation for the advancement of scientific or engineering knowledge or improved effectiveness of commercial products.

In addition, California tax law allows businesses that experience a loss for the year to carry this loss forward to the next year in order to offset income in the following years. New businesses can carry over 100 percent of their losses for 10 years if the loss is in their first year of operation, 100 percent over seven years if the loss is in their second year of operation, and 100 percent over six years if the loss is in their third year of operation. Existing California business can carry over 50 percent of their losses for five years.

Future Policy Areas

Although the policy environment in Michigan and California regarding advanced automotive is limited currently, in the future, with the development of new automotive technologies, the states may choose to regulate the area further. Three technologies that have shown promise in the testing phase are hydrogen vehicles, hydraulic hybrids, and electric automobiles.

Hydrogen

Although they are still in development, hydrogen vehicles represent an attractive option for reducing petroleum consumption and improving air quality. Hydrogen vehicles are powered by fuel cells that produce no air pollutants and few greenhouse gases. If fueled with pure hydrogen, fuel cells emit only heat and water as a byproduct.

Hydrogen fuel cell vehicles are not yet commercially available. However, they are currently being demonstrated in light- and heavy-duty applications in fleets throughout the country. For example, Honda has placed several prototype light-duty FCX fuel cell vehicles city fleets, and California transit agencies are demonstrating fuel cell buses in revenue service.

The U.S. Department of Energy (DOE) is dedicated to hydrogen vehicle research and development. From using hydrogen in internal combustion engines to building a nationwide network of hydrogen refueling stations, studies in all aspects of hydrogen vehicles are being conducted by DOE's FreedomCAR and Vehicle Technologies and Hydrogen, Fuel Cells, and Infrastructure Technologies (HFCIT) Programs.

In addition, the HFCIT Program developed the Controlled Hydrogen Fleet and Infrastructure Demonstration and Validation Project, which conducts tests on the performance of fuel cell vehicles and the supporting hydrogen infrastructure. Insights are fed back into DOE's research and development program to guide and refocus future studies.

Hydraulic Hybrids

A hybrid hydraulic system uses an accumulator (which stores energy as highly compressed nitrogen gas) and one or more hydraulic pump/motors rather than the battery pack, electric generator/motor and power electronics used in electric hybrids.

Like their electric cousins, hydraulic hybrids can come in different configurations with different benefits.

A milder form of hydraulic hybrid is termed Hydraulic Launch Assist (HLA). With HLA, a reversible hydraulic pump/motor and accumulators are added to optimize fuel economy, while keeping the vehicle's conventional engine and transmission. Regenerative braking captures the braking kinetic energy. Earlier EPA prototypes stored and re-delivered about 80% of braking energy back to the wheels. The efficiency of this regenerative braking makes a hybrid hydraulic design very attractive for vehicles operating in stop-and-go conditions. Benefits of HLA include a 25%–45% improvement in city fuel economy, with a concomitant reduction of emissions by 20%–30%; better acceleration, less brake maintenance and reduced operating costs.

The diesel-hydraulic hybrid under development for UPS, though, is a full series hybrid system that incorporates the new EPA Clean Diesel Combustion engine for further emissions benefits. The CDC engine powers a hydraulic pump rather than a generator/motor. A hydraulic drivetrain replaces the conventional drivetrain and eliminates the need for a transmission. Regenerative braking captures additional energy for the hydraulic system. Primary hydraulic components consist of two hydraulic accumulator vessels, one engine hydraulic pump, and one integrated rear-drive hydraulic pump-motor assembly

Electric

A plug-in hybrid electric vehicle (PHEV) is a hybrid which has additional battery capacity and the ability to be recharged from an external electrical outlet. In addition, modifications are made to the vehicle's control software. The vehicle can be used for short trips of moderate speed without needing the internal combustion engine (ICE) component of the vehicle, thereby saving fuel costs. In this mode of operation the vehicle operates as a pure battery electric vehicle with a weight penalty (the ICE). The long range and additional power of the ICE power train is available when needed.

Given suitable infrastructure, PHEVs could also be recharged while the user drives. The PHEV establishes contact with an electrified rail, plate or overhead wires on the highway via an attached conducting wheel or other similar mechanism. The PHEV's batteries are recharged by this process - on the highway - and can then be used normally on other roads. This provides the advantage of virtually unrestricted highway range. Since most destinations are within 100 km of a major highway, this reduces the need for expensive battery systems.

The technology for such infrastructure is old and well established. Electricity and infrastructure costs can be funded by toll revenue, gasoline taxes or other sources. PHEVs are commonly called "grid-connected hybrids", "gas-optional hybrids" (GO-HEVs), "full hybrids", and are sometimes called HEV-30 (for instance, to denote a hybrid with a thirty-mile (50 km) electric range, compared to a HEV-0 (a non-plug-in hybrid). However, Ford, GM, and Toyota have all used the term "Full Hybrid Technology" to describe configurations that allow electric-only operation at low speeds (yet not PHEVs). Two other PHEV names used by a major U.S. automotive supplier and in a 1999 SAE paper are "energy hybrids" and "true hybrids". PHEVs can also operate in a mixed-mode where both gas and external electricity are used simultaneously to increase gas mileage for a particular range, usually at least double that of its electric-only range, but highly dependent upon the stage length between rechargings.

Policy Recommendations

Advanced automotive in Michigan is an industry that has flourished despite the state's poor economic standing. This, we believe, speaks to the industry's strengths and therefore we recommend that advanced automotive by and large be left alone. It does not need regulation, nor does need specifically tailored programs to encourage its growth. However, more generalized strategies aimed at entrepreneurs of any type will be helpful to this industry's command of talent and resources in the face increased competition from other subsidized industries in the State.

Among these recommendations are an increase in funding and support for the SmartZones. Many of Michigan's SmartZones have molded themselves into business accelerators aimed at specific industries, advanced automotive being one of them. This kind of support is necessary to keep the industry among the top in the state. Second, the state can make more pre-seed capital available for fledgling small businesses in Michigan, including advanced automotive firms. Last, one of the most important outcomes from these policies is not just the strengthening of Michigan's advanced automotive industry, but the diversification of firms in that industry. Our continued reliance on the big three auto companies is hurting this state economically, and in the long run a diversification of firms is in our best interest.

Appendix I

Figure 1 The changing nature of the auto industry value chain

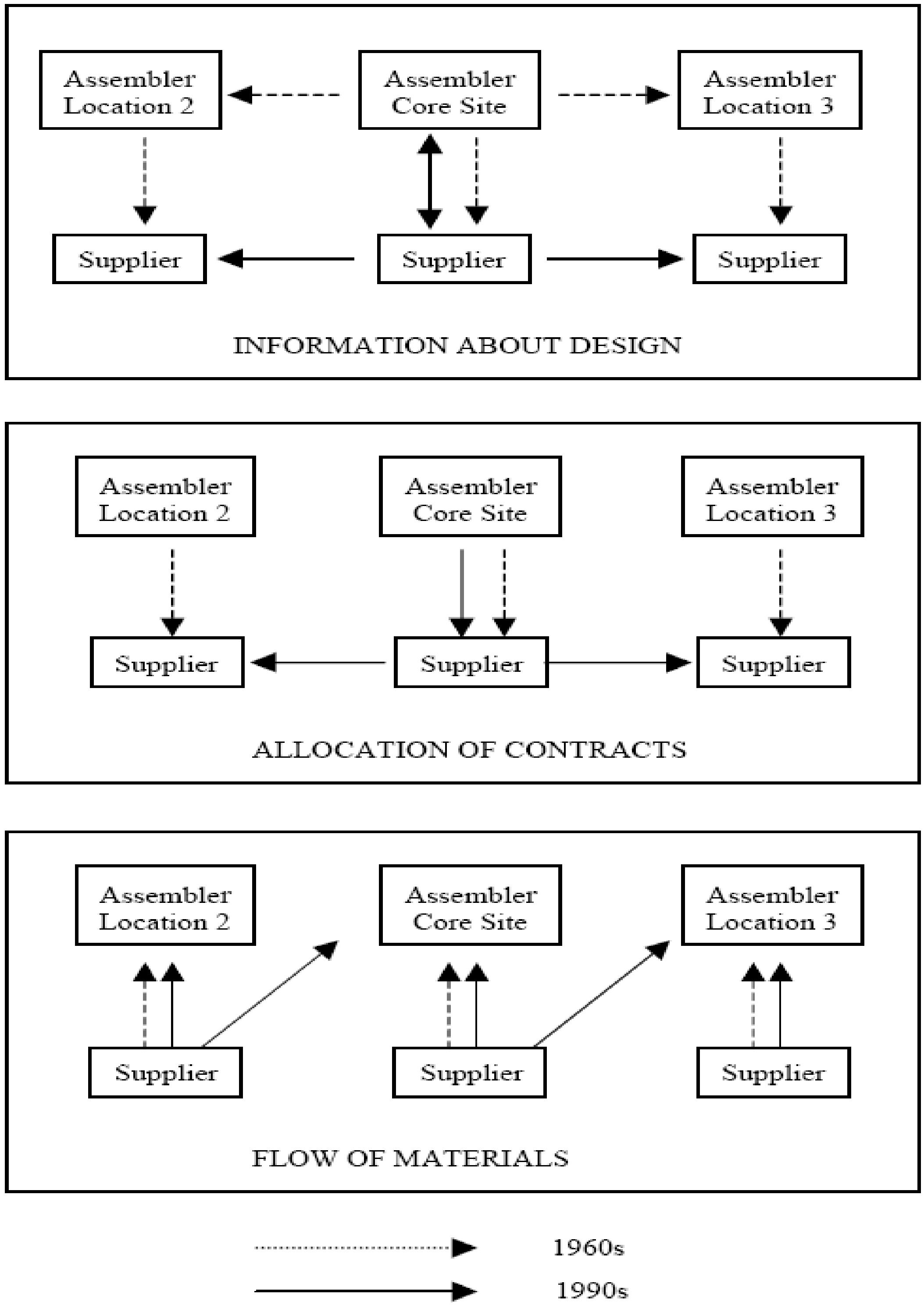


Figure 2

ISO 9000

ISO 9000 is a series of quality management systems standards created by the International Organization for Standardization (ISO), a federation of 132 national standards bodies. The ISO 9000 quality management systems (QMS) standards are not specific to products or services, but apply to the processes that create them. The standards are generic in nature so that they can be used by manufacturing and service industries anywhere in the world. First released in 1987 and revised in a limited manner in 1994, they underwent a major overhaul in 2000.

The most important revised standard, ISO 9001:2000, uses a simple process-based structure, which is more generic than the old 20-element structure of ISO 9001:1994, is consistent with the plan-do-check improvement cycle used in the ISO 14000 environmental management systems standards, and adopts the process management structure widely used in business today. ISO 9001:2000 addresses an organization's quality management system requirements, in order to demonstrate its capability to meet customer requirements, and applies to all generic product categories, such as hardware, software, processed materials and services.

ISO 9001:2000 registration gives the organization the benefit of an objectively evaluated and enforced quality management system. It is a tangible expression of a firm's commitment to quality that is internationally understood and accepted. ISO 9001:2000 registration is carried out by registrars, accredited organizations that review the organization's quality manual and other documentation to ensure that they meet the standard, and audit the firm's processes to ensure that the quality management system described in the documentation is in place and is effective.

QS-9000

QS-9000, released in 1994, is the ISO 9000 derivative for suppliers to the automotive Big Three, DaimlerChrysler, Ford and General Motors. This quality management system standard contains all of ISO 9001:1994, along with automotive sector-specific, and Big Three and other Original Equipment Manufacturer (OEM) customer-specific requirements.

QS-9000 applies to all internal and external suppliers who furnish parts or materials for production or service, along with heat treating, painting, plating or other finishing services, directly to the Big Three, embracing the latest technology and taking a preventive approach to quality issues. A QS-9000 quality management system provides for continual improvement, emphasizes defect prevention and reduces waste in the supply chain.

General Motors and DaimlerChrysler require their production and service suppliers to register to QS-9000, while Ford requires conformance to the standard.

Figure 3

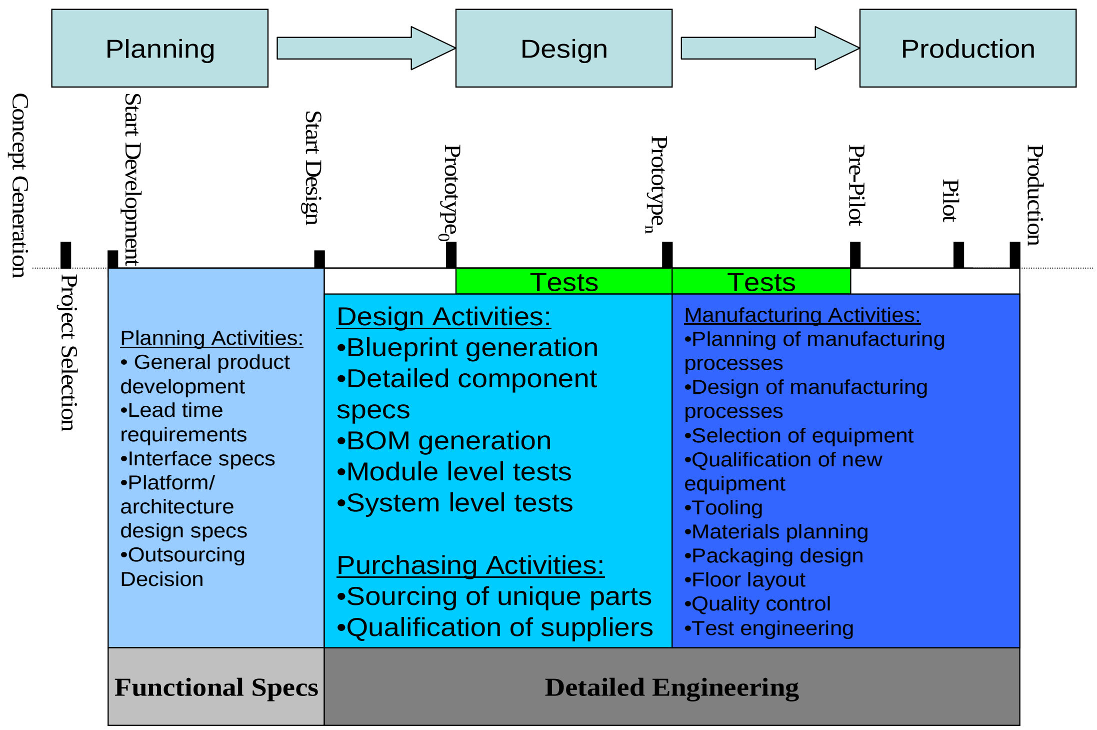


Figure 4

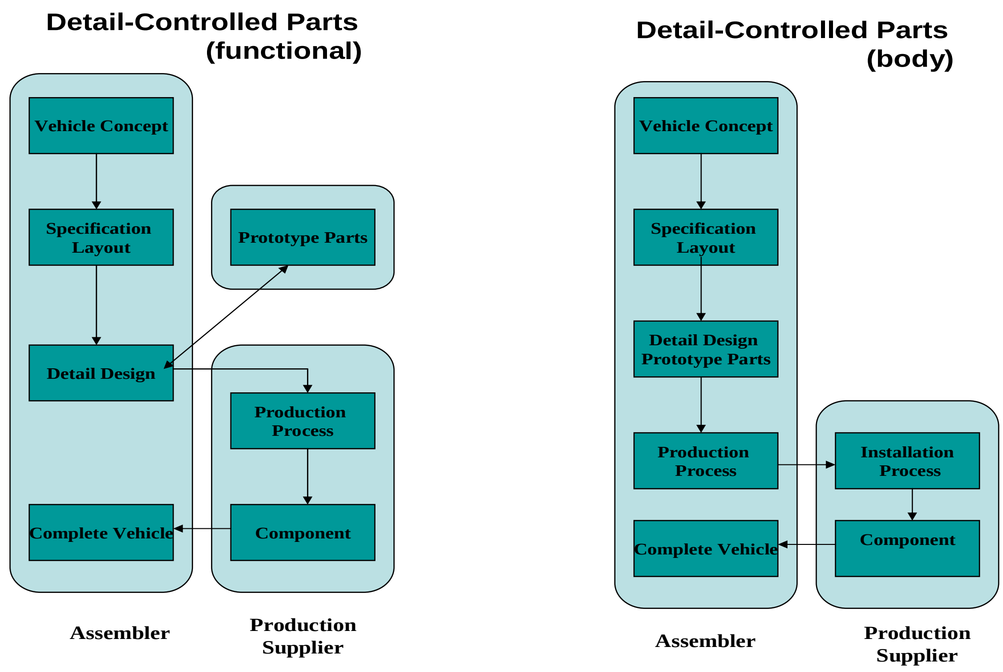
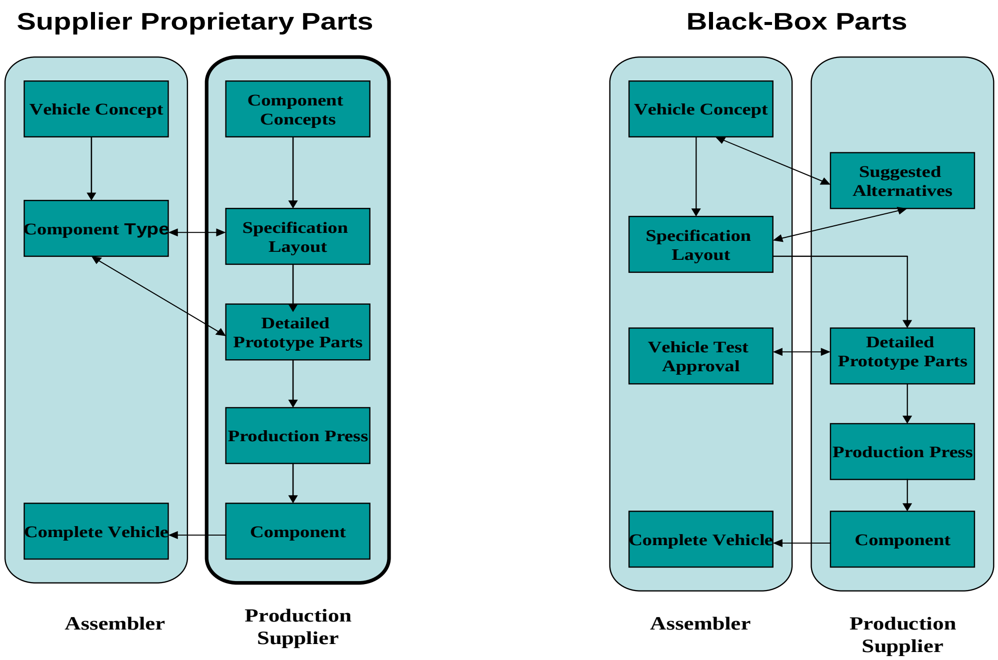


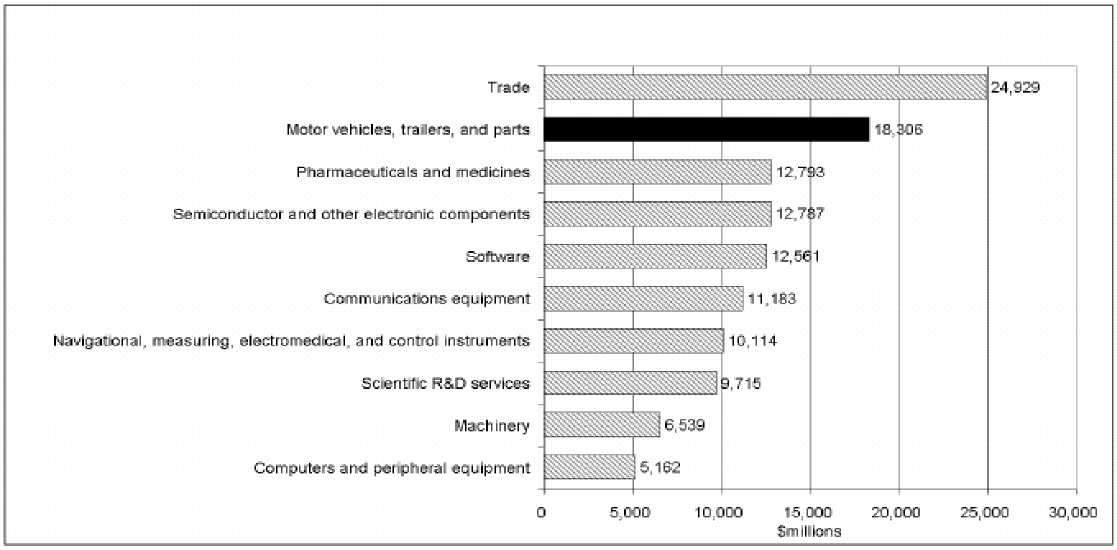
Figure 5


Supplier Proprietary Parts
Vehicle Concept
Component Type
Complete Vehicle
Component Concepts
Specification Layout
Detailed Prototype Parts
Production Press
Component
Assembler
Production Supplier
Black-Box Parts
Vehicle Concept
Specification Layout
Vehicle Test Approval
Complete Vehicle
Suggested Alternatives
Detailed Prototype Parts
Production Press
Component
Assembler
Production Supplier

Appendix II

<u>Figure 1</u>

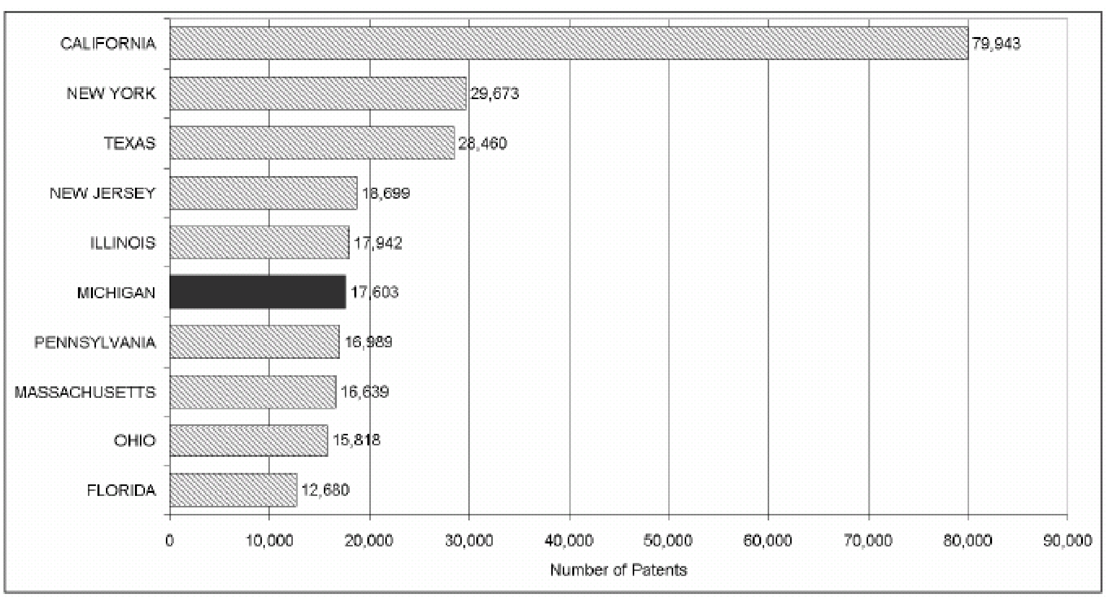
R&D Spending by Industry – 2000
Motor Vehicle is 2nd of 39 Major U.S. Industries



Source: National Science Foundation, <u>Research and Development in Industry: 2000,</u> Table E-2.

<u>Figure 2</u>

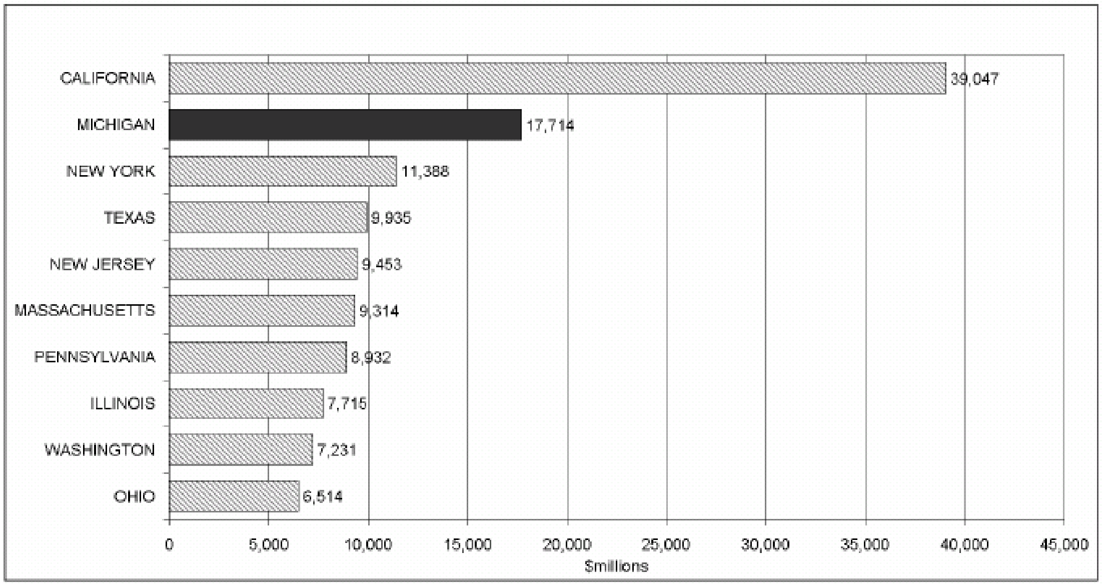
States Ranked by Patent Issued 5-Year Period: 1997 – 2001
Michigan Ranked 6th of the 50 States



Source: U.S. Patent and Trademark Office, <u>PATENT COUNTS BY CONTRY/STATE AND YEAR: UTILITY PATENTS, JANUARY 1, 1963 – DECEMBER 31, 2001</u>

Figure 3

States Ranked by Industrial Research & Development – 1999
Michigan Ranked 2nd of the 50 States



Source: National Science Foundation, Division of Science Resources Statistics, Research and Development in Industry: 1999, Table 1-32

Figure 4

Big Three Auto
Technology Employment Questionnaire Results

Total 1998	U.S.	Michigan	Michigan %
Auto Employment	492,887	235,807	47.8%
High-Tech Auto Employment	47,548	37,489	78.8%

Source: Special Company tabulation – 1999, OSAT/UMTRI/University of Michigan.

Figure 5

1998 High-Tech Employment
as Percentage of Total Big Three Auto Employment

Other States	Michigan
3.9%	15.9%

Source: Special Company tabulation – 1999, OSAT/UMTRI/University of Michigan.

Figure 6

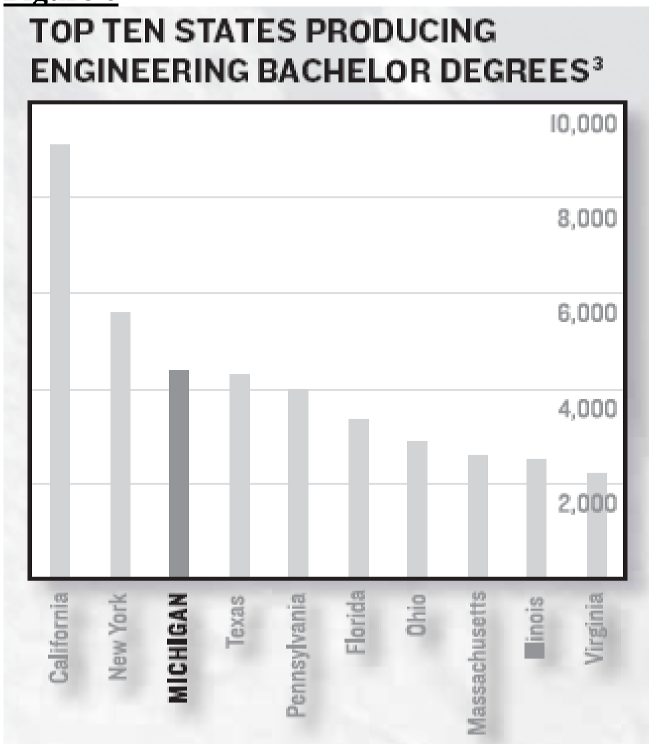
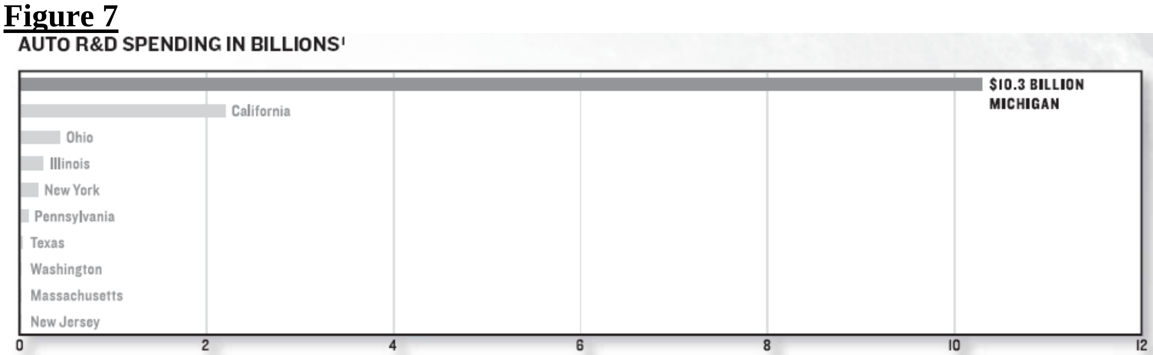


Figure 7



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