Automotive Product Technology and Worker Training

Part One: The U.S. Automotive Industry— A Contextual Paper

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by
Michael S. Flynn
David J. Andrea

The Office for the Study of Automotive Transportation
The University of Michigan Transportation Research Institute

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The Office for the Study of Automotive Transportation
The University of Michigan Transportation Research Institute
2901 Baxter Road
Ann Arbor, MI 48109-2150

Phone: 313-764-5592
Fax: 313-936-1081

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16. Abstract

This report is presented in two parts. The first part presents a contextual, U.S. automotive industry overview highlighting the major driving forces, market share gain strategies (reducing product development lead time, product design, competitive offerings, and quality/value packaging), cost reduction efforts (capacity utilization, product redesign, and outsourcing), and regulation (CAFE, Clean Air Act, and safety).

The report's second part presents thirteen memos covering major product technology changes by vehicle subsystem (assembly, engine, body structure, etc.). The memos cover product and process changes over the next ten years and highlight the general labor implications. For each memo a product technology summary sheet is given listing the current manufacturing process and configuration, driving change forces, and likely outcomes for the subsystem's major components.

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This paper reviews and discusses issues underlying the competitive dynamics that will affect the U.S. automotive industry and market throughout the decade of the 1990s. It also provides background information and support for a series of briefing memos (part two of this report) on possible developments in automotive product technology. The University of Michigan's Office for the Study of Automotive Transportation developed these memos for the American Society for Training and Development for its work with the UAW-Chrysler National Training Center. While both parts of this report, to some extent stand alone, we assume that persons working with the UAW-Chrysler National Training Center will have access to both.

Industry Overview

The U.S. automotive industry emerges from the decade of the 1980s dramatically changed in many ways:

- UAW International membership declined by 34% (514,000 jobs lost between 1979 and 1989) as Big Three market share fell, outsourcing to independent suppliers increased, and automation and organizational changes increased productivity;

- market share of traditional domestic-produced passenger cars fell from 76% in 1979 to less than 59% in 1990, as new segments emerged, consumer loyalty fell, and the Big Three struggled to increase perceptions of their vehicles' quality and value;

- market share of traditional domestic light trucks recovered from a decade low 78% in 1986 to 83% in 1990, while overall truck share of the total light vehicle market increased from about 25% to 33%;

- total annual market growth for the decade averaged less than 1% per year, but Toyota, Nissan, Honda, and GM each introduced new-brand franchises and the Big Three expanded their use of captive import nameplates; and

- joint ventures, mergers, and acquisitions eliminated old companies, created new ones, and complicated competitive forces.

These changes left no industry tradition, practice, or management concern unchallenged—material fabricators and part/component suppliers, assemblers, unions, and various levels of government. They created excess capacity, lowered margins, and stretched the capabilities of the entire workforce. Nor will these issues decline in importance through the 1990s, although it can be said that the need for change is now widely recognized, and significant responses and transitions are underway. The industry's challenges will be further complicated in the 1990s by government regulation that will force responses across a range of industry challenges by simultaneously increasing safety, fuel economy, and emission standards for passenger cars and light trucks. Successful companies will be those able to identify and address multifaceted problems in a timely, efficient, and effective manner.

Unlike years past, when one, or perhaps even two, of the Big Three faced serious risks to market share, profit, or job levels, today, each of the Big Three companies faces these challenges. Each is trying to improve its competitive position against the other two, but most particularly against Japanese competition. To become more competitive, each of the Big Three must master three substantial competitive challenges simultaneously: regain market share against heightened international competition; reduce costs in a period of rapid change; and conform to intensified and more complex regulatory pressures. These competitive challenges will place tremendous demands upon people, product, process, and plant.

U.S. Industry Driving Forces

Numerous competitive drivers, challenges, and specific events will force changes in product technology throughout the 1990s, and those changes will themselves exert major influence upon changes in process technology. Product technology change can influence both the number and task structure of jobs at an automotive manufacturer like Chrysler. Change in product technology can eliminate jobs, as old products are retired, and their replacements require lower labor content, or are sourced from other companies or plants. The specific tasks and capabilities required to produce new or replacement products may be quite different: imagine the changes in jobs associated with the replacement of mechanical carburetors with electronic fuel injection to control the air:fuel mixture.

No one can forecast with great accuracy what changes in product technology will most significantly affect the number and structure of jobs at Chrysler over the coming decade. Much of that change will be incremental, gradually influencing jobs throughout the period, while some will be more revolutionary, building on breakthrough developments in material, technology, and design. Nevertheless, there are a few drivers that almost surely will have broad effects throughout the industry, and thus merit consideration now and monitoring in the future. Companies that anticipate change are typically better equipped to respond to it effectively, rapidly, and humanely. We are persuaded that there are three primary drivers, or clusters of factors, that will shape and influence the likely development of product technologies in the 1990s. These are 1) the effort to gain market share; 2) the effort to reduce costs; and 3) the responses required by regulatory initiatives.

Market Share Gain

The domestic manufacturers, including Chrysler, face two fundamental issues in the pursuit of increased market share. First, they must be able to predict and deliver product that satisfies customer desires and expectations. This ability is at the root of recapturing lost market share. Second, and perhaps more difficult, they must overcome negative consumer perceptions and convince customers that new models justify consideration. For example, a 1990 J. D. Power and Associates survey indicated that some 40% of buyers in the new car market were not even considering any GM makes. To address these issues vehicle manufacturers must focus on improving their methods of operations to:

- reduce product development and delivery lead time;
- meet increasingly sophisticated and turbulent customer preferences in exterior and interior product design;
- provide competitive offerings that satisfy all facets of customer sales and service demands; and
- deliver product quality and technology in a high value package.

<u>Reducing product development and delivery lead time</u> continues to be a key driving force. Many academic and industry studies have shown significant gaps between Japanese and U.S. standards. Most analysts agree that the best Japanese firms develop new platforms in about three years, while U.S. firms require roughly five years and more than twice the number of engineering man hours. This difference is significant because it results in a shorter planning horizon (manufacturers need to predict consumer preferences three years ahead versus five years), increasing the likelihood that the vehicle will match the market. Also, Japanese lower development supports rapid model turnover, and should a model fail in the market, its replacement is not far behind—some four years for the Japanese and nine years for the Americans. In addition to providing a hedge against poor market performance, reduced lead time supports a continual flow of new product styles into Japanese showrooms, which stimulates a constant flow of customers into the showrooms. Above all other considerations, exterior and interior styling is still probably the single most important factor in consumers' decisions, both to replace a vehicle before the end of its useful life and to purchase a specific vehicle. No one wants an outdated or new "dog" in their driveway.

Another important advantage conferred by quick, low-cost development capabilities is the ability to expand platform and body styles to cover more and smaller market niches or customer clusters. Japanese producers have some 72 separate platforms worldwide while U.S. firms produce 36. Some 572 different nameplate and body styles were offered for sale in U.S. dealerships in 1989, and 62% of them were foreign. The ability to produce a multitude of styles is critical to succeed in a U.S. market characterized by changing consumer tastes and diverse needs.

In the opinion of many analysts, Chrysler, especially, must reduce its product development time. Many consumers view Chrysler styling as dated and unexciting, and that may account for its falling market share over the past few years. Certainly price, quality, and performance reviews do not account for that loss. Chrysler's domestically produced share in passenger car sales has fallen from above 10% in 1988 to under 8% in 1990, and Chrysler outsold Honda by only a razor-thin 6,000 cars in 1990.

Manufacturers are using hard and soft technologies to reduce product development lead times. Hard technology involves embedding work in machines, most notably in computers and automated manufacturing equipment. The automotive manufacturers, including Chrysler, are implementing hard technologies to improve the process flow between design, engineering, prototype, and manufacturing. Computer Integrated Manufacturing (CIM) is an example of a hard technology system. CIM serves to integrate, ideally, all product development stakeholders into a common system where designs, engineering changes, and other functions are equally available on a real time basis. With this integration, CIM provides the linkages to develop vehicles from a systems viewpoint, optimizing the function of the entire vehicle. The application of computers to all forms of data analysis, design, and other product development-related functions forces consolidation in some areas (clerical), reallocation in others (salary), and new required skills (computer-aided designs) in still others. If properly planned and executed with the proper staffing of technically-trained human resources, CIM offers improvements in product quality, rapidity of response to customer changes, and leverage through the updating of earlier designs, rather than complete creation of new designs. CIM technology heightens the need for continual on-the-job training.

Soft technology involves embedding routine in human activities, such as business practices, operational processes, and job procedures. Just-In-Time (JIT) manufacturing is an example of a soft technology. JIT is a philosophy of pulling product through a system, allowing only a bare minimum of work in process material. This reduces both stock and in-process inventory, forcing a top quality first-time-through approach, and permits more rapid changes to correct defects and introduce customer-demanded changes. However, because of the lack of system slack, JIT does not permit antagonistic customer-supplier, labor-management, or other internal or external relationships.

When JIT is implemented throughout the entire automotive enterprise, from first design to customer purchase, domestic manufacturers will no longer rely upon a 60-day new vehicle inventory on dealers' lots. This inventory has served two purposes: first, it acts as a buffer for factory output, and second, it serves the vast majority of buyers who buy "off-the-lot" rather than special order a vehicle. The cost of carrying this inventory is partially shared by the factory, but in slow selling periods, it is supported primarily by the dealer (who buys the vehicle from the factory). If turnaround time between a dealer order and delivery could be improved, there would be a great incentive to eliminate this inventory carrying cost because, except for the impulse buyer, it provides little consumer value. Several industry executives have mentioned 30 days as a reasonable target. This might result in a competitive advantage to the company that reduces the financial carrying costs while maintaining customer satisfaction.

Product design, especially exterior styling, is one of the most important factors in new car purchases. Buyers want a vehicle that looks attractive in their driveway and communicates their desired image. Since styling is a significant factor, manufacturers are constantly revising exterior and interior styling to remain current with prevailing design trends, and "fresh" against competitor offerings. "Outdated" designs do not attract needed showroom traffic and such vehicles are at a market disadvantage. Therefore, mass, or full-line, manufacturers pursue rather aggressive schedules of minor and major sheet metal changes along with paint, trim, and material changes. As more manufacturers and brand franchises compete in the U.S. market, the possible number of new product introductions increases dramatically. Thus, all manufacturers must maintain substantial product introduction schedules. In fact, pressure to introduce new product is so intense that the industry's traditional Fall model introduction has seriously eroded, and new products are introduced throughout the year.

This intense product development effort places a premium on time. Manufacturers and suppliers are reducing the time to market by reorganizing staffs into product development teams, outsourcing product development activities to engineering service firms and suppliers, and using hard technology such as CIM. As discussed above, the best Japanese firms are considerably faster to market than the Big Three. To some extent, technology differs; the Japanese are further along in the use of sophisticated, highly-integrated design, product and process engineering, financial, and other relevant-experience data bases. These data bases leverage information to its greatest extent, allowing incremental improvements on earlier work and the optimization of the entire vehicle system. However, it appears the most significant difference between the Japanese and American product development process is in human resource organization. In this regard, Japan is viewed as the model and the American companies are moving as quickly as possible to emulate Japanese product development structures. Chrysler, for example, recently appointed high level executives to head its platform groups, attributing this change to modelling Japanese practice.

Chrysler's product development effort is based around specific vehicle platform teams, as are Ford's, GM's and the Japanese. These teams are multi-disciplinary, involving product and manufacturing engineering, finance, purchasing, parts and service activities, and other related functions. This multi-disciplinary team structure significantly differs from previous product development systems. Those systems were highly sequential, and each individual function operated in isolation, within its own sphere of responsibility. Current team structure facilitates communication, reducing the likelihood of engineering changes as the individual vehicle subsystems are integrated into a complex vehicle during pilot build. The platform teams are, in turn, organized into groups representing market segments such as large car, intermediate, etc. These larger groups coordinate product offerings to produce a competitive product portfolio in line with corporate objectives and marketing staff analysis.

Platform team organizations operating in a simultaneous engineering mode have many advantages over old, sequential operating methods. They possess a clear advantage in vehicle packaging. Packaging refers to the design and engineering effort required to provide the necessary space for passengers, cargo, engines, transmissions, and other major system components, while meeting the constraints of vehicle size and weight, structural integrity and safety, manufacturability, assembly, and future field service. When all functions work together as a team, designs can optimize the whole vehicle, rather than its subsystems and parts. Reduction in vehicle size requires increased creativity to fit components into the engine bay area. This is also true of the instrument panel, particularly in respect to increased option content. This requires massive wiring harnesses and more complex air duct routing. Working together under a platform manager, component development groups should be able to make better cost/benefit decisions, keeping the overall vehicle within cost and weight objectives.

Competitive offerings are mandatory, especially in a market that offers approximately 45 brand names (e.g., Plymouth, Buick, Ford, Toyota) vying for the customer's attention. And, of course, each of these 45 brand names market multiple nameplates (e.g., Acclaim, LeSabre, Mustang, Tercel) making the U.S. one of the world's most nameplate-saturated markets. This competition requires that every vehicle attribute important to the customer be best-in-class; if they are not, no longer will brand-loyal customers have numerous alternative choices for their next purchase decision. This forces all manufacturers to pursue continuous improvement across interior and exterior styling, engine and transmission offerings, ride and handling characteristics, and new customer convenience features, as well as pricing, warranties, and dealer service.

The Big Three have been under tremendous pressure to improve their products to the level of technology, quality, and durability that customers attribute to Japanese vehicles; and the level of handling and interior ergonomic sophistication they attribute to European vehicles. The Big Three do not have the internal financial or human resources to support many simultaneous vehicle, powertrain, and other vehicle improvement programs, especially at Chrysler. The continuing pressure to introduce new product, combined with scarce resources, has led the Big Three to enter into numerous joint venture activities to provide needed product.

Joint ventures take on many different forms and involve a variety of risks to existing workforces. First, the Big Three depend upon their Japanese partners for complete vehicles. This is essentially the complete outsourcing of all vehicle engineering and production activity. The resulting "captive" sale, whether imported or produced in a U.S. transplant assembly plant, significantly, if not completely, substitutes foreign for domestic employment. Reliance on other manufacturers for vehicle production results primarily from the desire to be a full-line marketer (from entry-level subcompacts through performance and luxury specialty cars), but not a full-line manufacturer.

The Big Three each import a number of subcompact vehicles because, they argue, domestic production is not cost competitive. Therefore, GM imports Isuzu and Suzuki products (Geo) from Japan and Daewoo product (LeMans) from South Korea; Ford imports Festiva from Taiwan and Tracer from Mexico, and Chrysler imports Mitsubishi models (Colt) from Japan. Manufacturers might source complete vehicles to satisfy market niches with volumes too low to justify internal production (for example, the Dodge Stealth from Mitsubishi or the now-defunct Mercury Merkur models from Ford of Germany) or to meet an immediate need before a segment expands and internal production may begin (Chevy Luv and Ford Courier compact pickup trucks through the 1970s).

However, these strategies pose risks. First, subcompact product is needed to attract first-time buyers to the dealerships, and the old Sloan goal of producing "a car for every purse and purpose" still has merit because repeat sales are less expensive than conquest sales. Second, retreating from segments permits competitors to build production volumes and sales bases in the market, and that can fund their efforts in other segments, as has happened with Japanese producers. Third, each vehicle segment has its own distinctive challenges, and the lessons it provides may confer benefits and learning that support efforts in other segments. Fourth, even small volume models can confer market distinction, as Corvette has done for Chevrolet; most U.S. consumers probably know that the Stealth is built by Mitsubishi.

Access to foreign design creates a second motive for joint ventures. The Cadillac Allante, with its body designed and supplied by Italy's Pinninfarina, is an example of this strategy. The basic need for engineering capacity, as well as the ability to tap into sources of creative innovation provides a third joint venture incentive. An example of this strategy is GM's acquisition of Lotus for a source of advanced engine and suspension designs. Chrysler's joint venture with GM's Hydra-matic Division, New Venture Gear, is a good example of a fourth reason for joint ventures, the attempt to balance out component capacity requirements. GM's Hydra-matic operations were under-utilized and Chrysler needed additional four-wheel drive transfer case capacity. One final joint venture motive is the desire to develop a domestic operating base for market access and/or a "good corporate citizen" image. Many Big Three Mexican operations are examples of this strategy, driven initially by Mexico's domestic content legislation; Chrysler's use of Styr to assemble and distribute the mini-van in Austria may also fit here.

Quality/high technology in a high value package is increasingly the name of the automotive game as manufacturers face more sophisticated customers. Comparative information on all product offerings is readily available, and its sources range across all media, from books and newspaper reviews to buff magazines and television programs. Motorsports and auto shows also convey a significant amount of product and industry information. These public sources, combined with personal experiences and personal conversations, create the basic underlying perceptions of product quality and value. Japanese manufacturers have prospered in the U.S. market by first, delivering the perceived quality of fuel economy and low operating expenses in the 1970s, then durability and reliability in the 1980s, and now, advanced powertrain and suspension technology and sophisticated interior designs at the beginning of the 1990s. The Big Three are currently at a significant image disadvantage compared to the Japanese and each has major marketing campaigns underway to correct this: GM's "Where Quality Meets the Road," Ford's "Quality is Job One," and Chrysler's "Advantage" programs.

Some industry observers argue that cost and quality are converging, and that the Big Three are becoming equivalent, if not completely equal, to the Japanese. Thus, they argue, cost and quality will soon cease to differentiate vehicles in the market. The inherent risk in this view is highlighted above: "quality" may be perceived in many different ways, and what may be an unimportant quality attribute or an adequate quality level today may be viewed quite differently tomorrow. The ability to recognize such market differentiators and developments rapidly, and respond quickly, will be a critical success factor in the 1990s.

There is currently much debate within the manufacturers' engineering centers as to the most effective way to deliver vehicle performance attributes. One camp believes the customer does not value the underlying technology involved, but only really cares about the resulting acceleration, handling, ride, and other performance characteristics. Another camp contends that customers are comparing competing technologies and today view advanced materials as better than basic steel and iron, multi-valve overhead cam engine heads as superior to dual-valve pushrod designs, and making numerous other such comparisons. The Japanese are moving aggressively to install "high tech" features on vehicles. Many Detroit engineers are fearful of a broad-based application of technology for the sake of technology—as they should be. However, an extreme resistance to product innovation in some cases may place the product at a significant market disadvantage.

Another important variable in this discussion is customer purchase price—the basis of "value." Product innovation, unless it results in a compensating cost reduction elsewhere is never "free." Innovation required by safety, emission, or fuel economy regulation applies to all manufacturers, and, thus, a competitive advantage may be found by achieving these standards in the most cost effective manner. Firms such as GM have economies of scale to support the large research organizations that create such innovation, and that disadvantages smaller firms like Chrysler, especially in an environment of regulatory-driven innovation.

The restricted funds that companies can dedicate to non-regulatory innovation must be directly related to satisfying either existing or new customer wants. With new vehicle prices averaging over $16,000 and new monthly loans averaging 53 months, mass market customers will be careful with their money. Therefore, application of technology must occur at the lowest possible cost and achieve the most positive customer perceptions, in terms of improved vehicle characteristics, lower operating costs, or other such attributes. This forces manufacturers to control their costs and thoroughly understand their markets.

Cost Reduction

The domestic automotive industry today faces pressures to reduce costs in all its business activities, from marketing and design through manufacturing and distribution. The necessity to maintain a competitive cost structure creates a productive discipline throughout the whole system and provides the revenues required to support profit margins for investors, and investments in people, product, and process.

Capacity utilization and manufacturability have become ever more important corporate success factors as Big Three market share has declined through the 1980s. Historically, the domestic automotive market has been cyclical, with sales peaks every four to five years, which are separated by a substantially lower sales year or trough. Chrysler, Ford, and GM planned their production capacity to meet forecasted peak sales demand, and that would typically be three to four million units above the last trough. The industry would manage these peaks through utilizing the approximately 15% "reserve" capacity built into the system and, of course, overtime. With this planning, the industry labor force faced large employment swings, with workers experiencing layoffs and overtime, depending on the point of the sales cycle. New management philosophies in the face of new competitive challenges may result in changes in this traditional operating method, although both Chrysler and Ford were extremely cautious about adding capacity during the last peak period of the sales cycle.

The record U.S. sales year was 1986, when total sales reached about 16.3 million units. However, because of declining Big Three sales share and reliance on captive vehicles, 1986 was the first record sales year that was not also a record production year for the domestic manufacturers. With a stagnant total market and that declining domestic production share, the 1980s brought Big Three capacity utilization rates to less than 70%, and that means that fixed costs must be spread over fewer sales. The market slide of the early 1980s and increased competitor participation reduced profit margins dramatically because prices could not be raised enough to cover internal cost structure pressures. This pressure forced both Chrysler and Ford into serious financial difficulties between 1980 and 1982, resulting in a severe reduction in passenger car assembly capacity through plant closings and conversions of plants to light truck capacity and internal component operations.

A comparison of Ford and GM throughout the 1980s highlights the importance of capacity utilization for operating costs, revenues, and profits. GM had the financial clout to survive the 1981-1982 recession without dramatic changes; however, as its market share has continued to plummet it too has reached a market share level that forces significant change. GM out-earned Ford in the early 1980s but by 1988/89 Ford out-earned GM for the first time in some 40 years. In 1979, GM produced 6.5 million vehicles in 27 major assembly plants. Using a vehicle assembly module "rule-of-thumb" that each assembly plant can produce 240,000 vehicles per year, GM was justified in operating 28 assembly plants—that is, GM operated above planned capacity. Ford, however, operated 16 assembly producing 3.1 million units—or operated 3 assembly plants more than it required. By 1989 the tide had turned: GM's production drooped to 4.7 million units, but GM continued to operate 27 assembly plants, although 1989 production justified only 20 assembly plants. Ford, on the other hand, had reduced its assembly capacity by the three excess assembly plants, operated at full-capacity and out earned GM. GM has already announced that it will close four assembly plants and it is likely to close an additional three.

Today's automotive industry is emphasizing an increasing involvement of manufacturing engineering in all aspects of its business, especially in product design and process change. The industry has relearned an important lesson: product design fixes so many parameters that it is a major determinant of the cost and quality levels of product manufacture. Product engineers had almost exclusive control of design decisions, and, when manufacturing engineers were involved, almost always prevailed in product decisions. However, as cost and quality pressures increased, the industry recognized the need to design products so that they could be manufactured or assembled with minimum cost and maximum quality. As discussed above, this "systems" approach involves all industry corporate functions and supports their participation in product development teams. Focus on the "system" of manufacturing automobiles is also influencing the industry's approach to manufacturing changes on the shop floor. There is now a basic understanding that automation in and of itself will not necessarily decrease costs or improve quality. In fact, the industry has learned some expensive lessons about automation, because automation can result in increased costs due to higher fixed to variable cost ratios, lower flexibility, and lower "up-time." Most of these problems are not inherent in automation, but result from poor planning, implementation, and execution. In particular, the industry is refocusing its automation efforts to the entire factory, rather than focusing on automating isolated processes or subsystems, without regard to prior or subsequent activity or operations.

Better product and process designs are promoting system flexibility. As capacity is reduced and production consolidated and rationalized, the flexibility to produce multiple products simultaneously or to support quick product change-overs can promote employment security and stability, even though it will probably be at lower levels of employment. Plants will have greater flexibility to meet changing market demand for specific products and, thus, employment levels should be more stable. The greater capacity utilization that is possible with flexible plants should lower operating costs and make the plants more competitive, and that should make employment more secure. One labor-related effort to increase capacity utilization will likely be negotiations for three-crew plant operation.

Over the next five years, we expect capital expenditures to continue at record rates, assuming the general economy and financial system can provide the required funds. This money will be spent to improve manufacturing systems in all plants, with, perhaps, an initial concentration in engine and transmission facilities to support new product programs.

Product redesign often provides the occasion for significant changes in manufacturing and sourcing strategies, and thus represents a significant threat to current employment levels, and an opportunity for their expansions. An important change associated with design for manufacture or assembly is modular design, where a complete module or subsystem is designed to be manufactured or assembled as a unit, which is attached, mounted, or plugged-in at the point of final vehicle assembly. Modules or subsystems, such as complete instrument panels, wheel/brake/suspension "corners," doors and windows, front fascia, and others may be designed to allow the vehicle manufacturer to source a completed unit from a single supplier ready for final assembly. These modules are likely to develop as new vehicle platforms are introduced, and may restructure customer-supplier relationships into distinct tiers, similar to the Japanese industry. Modular sourcing is likely to shift some current work from the assembly plant to a supplier plant, so it is important for Chrysler employment levels that internal suppliers develop the capabilities to be first-tier, modular supplier. The simpler and more direct business relationships, which modular design and sourcing support, suggest that white collar workforces may be trimmed more than production workforces.

As this restructuring occurs, the Big Three are also demanding improved supplier performance on the traditional purchasing criteria: price, quality, delivery, engineering competence, and management responsiveness. The trend to modular, or systems suppliers requires suppliers to be more technically sophisticated. It forces suppliers to expand their product and process engineering capabilities and to develop advanced electronic communication capability to facilitate the transfer of engineering data, production schedules, and accounting information.

Manufacturers are holding the line on component prices, while demanding that suppliers take on increased responsibility, and that puts pressure on supplier profit margins. This results in tremendous pressures to reduce costs throughout the entire supply chain.

Outsourcing, buying rather than making parts and components, increased at the Big Three throughout the 1980s, primarily as a means of reducing costs, and largely dictated by emulation of the less vertically-integrated Japanese assemblers. It appears that these significant Big Three outsourcing trends of the early 1980s have now subsided and yielded to a more cautious and pragmatic sourcing strategy. This change is at least in part due to job security clauses of the UAW labor contract, international vehicle and component production efforts, and concerns for capacity utilization, cost, and product quality. The result is that some contracts are now coming inside, as well as some going to independent suppliers. There does appear to be a limit to outsourcing, since the industry currently seems to have a fundamental belief that vehicle assembly, engine, transmission, and electronic systems engineering and manufacturing should remain with the manufacturer. These operations are highlighted because they contribute substantially to the product's quality and differentiation. Since some 60-70% of a Chrysler vehicle's cost is purchased materials, components will remain in the cost reduction spot light. All components are under constant review and may come and go from Chrysler internal manufacturing operations. These decisions will probably be tied to individual vehicle platforms, and will probably change as conditions dictate. This increases the pressure on individual Chrysler internal suppliers to be competitive on cost and quality, and flexible so that they may capture available work. Each plant must be prepared to win contracts for new components on new platforms.

Regulation

The third major driver that is likely to influence employment levels and tasks throughout the 1990s is the regulatory activity of the federal and state governments. Regulation has always been an important driver of industry strategy, investment, and innovation. However, in the past, the various targets of regulation seemed almost to "take turns." The 1950s and early 1960s witnessed a stress on safety; the late 1960s, emissions; and the 1970s, fuel economy. These shifting regulatory emphases reflected the concerns and issues of the public and its political representatives. We expect the 1990s will witness similarly shifting concerns, although the pressure across a number of regulatory fronts is likely to increase, so that the industry will simultaneously face extreme pressures on all fronts.

These basic areas of regulation often generate conflicting demands. Safety rules tend to add extra weight to the vehicle, and that reduces fuel economy, while tuning an engine for emissions reduction might not provide safe freeway acceleration. Moreover, regulatory demands often involve conflicts with the automotive market and may decrease customer satisfaction. The general public wanted the Corporate Average Fuel Economy (CAFE) legislation to improve fuel economy and decrease the U.S.'s dependence on foreign oil, but when the cars were ready, the market preferred less fuel efficient vehicles because the price of gas had fallen and the supply was plentiful.

Moreover, many of us support general regulatory goals, but hope to avoid their constraints ourselves. Many public transit alternatives to private cars have received overwhelming public endorsement, but little ridership when they became available. For example, residents of the Bay Area in San Francisco supported rapid transit, but the BART system has extremely low levels of ridership. It is now clear that residents wanted the system for their neighbors to use, so the freeways would be less crowded for themselves. The core problem for the industry is that the regulatory agenda is largely driven by political and social concerns, and often fails to accommodate the business and technical realities facing the industry.

Both the industry and the buying public struggled through the first thirty years of regulation with a mix of good and bad outcomes. By the late 1980s, vehicle engineers had achieved a near miracle: auto emissions fell, fuel economy rose dramatically, acceleration times improved, horsepower to engine displacement ratios increased, vehicle operation and maintenance improved, while interior room remained relatively constant. However, in spite of the greatly reduced social costs of operating motor vehicles, there appears to be widespread public sentiment that even more needs to be done. It appears that the industry will likely face increasing performance standards in fuel economy, emissions, and safety, and that these will almost certainly develop simultaneously rather than sequentially. These regulatory pressures will make enormous demands on available capital and critcal human skill resources. If demands for these performance levels do not become important decision criteria for individual consumers, then success in meeting them will only keep companies in the marketplace, and confer little competitive advantage. Companies, like Chrysler, that find themselves relatively strapped for capital may have little opportunity to gain market share through aggressive product investment.

<u>CAFE</u> sets fleet average fuel performance standards for the manufacturers and imposes a scale of fines graded to the size of any shortfall. It is important to note that these fleet averages are determined for vehicles actually sold, not vehicles produced and offered for sale. Thus, a manufacturer, whose larger, less fuel-efficient vehicles are relatively more successful in the market than its smaller, more fuel-efficient vehicles, might face such fines. Moreover, the legislation calls for calculating CAFE separately for two fleets: a domestic (75% or more "domestic content," including Canadian content) and import (less than 75% domestic content). Performance in one fleet cannot offset performance in the other—except when the same car is produced in both fleets.

Chrysler's domestic CAFE performance has been superior to either Ford or GM, who have been permitted to use "credits" for exceeding the standards in earlier years to offset their failure to reach the standard the past two years. Unfortunately, while the public supports CAFE regulation, fuel economy has been less important in deciding which vehicle to purchase, and Chrysler sales have plummeted during that period of superior CAFE performance.

The separation of domestic and import fleets originally came into the CAFE legislation as a way to maintain jobs in North America, since it effectively prevented the manufacturers from sourcing all fuel efficient subcompacts from offshore. There is at least some suggestion that strategy may now fail, and force some production of larger, less fuel-efficient vehicles into the "import" category, if not actually into offshore production. The Big Three may now shift their sourcing strategies to lower the domestic content of larger vehicles by bringing in significant value in parts and components from abroad, including Mexico. Unlike Canadian, Mexican content does not fall into the domestic content category. For example, Ford has announced that the 1992 Crown Victoria and Grand Marquis will have 73% domestic content and thus will qualify as imports. Their relatively low CAFE performance can be offset against Mexican Tracers and Korean Festivas, and will not drag down the CAFE average of the domestic fleet. While this will lower levels of domestic employment for any such "shifted fleet" vehicles, losses will be small compared to losing entire vehicles to offshore production, whether large or small cars.

At this point it is unlikely that Chrysler will need to pursue any such shift in the CAFE designation of its vehicles. However, a new CAFE standard will be debated in Congress again this Spring, and any significant increase in performance requirements could damage the domestic industry and eventually result in moves to redesignate cars as import.

Any new CAFE bill will most likely be a variation of the Bryan bill introduced into the Senate last Fall. The debate on that bill can be fairly characterized as strong on political rhetoric and weak on industry analysis. The Big Three, UAW, foreign manufacturers, and trade associations lobbied strongly against this bill, in a rare show of industry unity. Proponents of the bill argued that Detroit has allowed their passenger car and fleet averages to slip over the last two model years and again needed the discipline of regulation. Unfortunately, low fuel prices and a strong economy had driven fuel economy even lower on the customer's hierarchy of purchasing criteria, and increased the standing of performance criteria. Foreign manufacturers' fleet fuel economy averages, particularly the Japanese, fell even more than domestic manufacturers in response to these same market shifts.

The Bryan bill required a passenger car fleet average increase of 20% by 1995 and 40% by 2001. This would have dramatic effect on virtually every current and future vehicle, engine, and transmission program. It might even force the cancellation of many programs, reducing consumer choice, lowering employment, and making uncertain the basic survival of our full-line manufacturers and even the automobile as our primary personal transportation method. It is likely that engine, transmission, vehicle downsizing, and advanced material programs will receive additional funding as the result of this legislation, although those investments would probably be targeted at survival, rather than enhanced market share.

Unfortunately, no one has projected the total "systems" cost of this legislation to the industry or consumer. It is interesting that the CAFE bill does not include a provision for the need to perform cost/benefit analysis, although that is characteristic of much regulatory legislation. Most countries regulate automotive offerings and gasoline consumption through fuel taxes and alternative transportation systems. The U.S. government tries to regulate the vehicle and fuel markets at the production point, without supporting alternative modes of personal transportation.

The Bryan bill may lose political support if oil production capabilities and prices are stabilized, and the 1990/1991 recession proves brief and/or mild. However, the Persian Gulf war may again raise concerns about the availability and price of oil, the original drivers for CAFE legislation in the 1970s. We must also note that the industry will be better served if it provides reasoned and sound arguments as to the costs and benefits of various CAFE scenarios, rather than rhetorical responses. A case for modest improvements might provide a way to continue improvements in new vehicle fuel economy while fleet turnover continues to achieve overall fuel conservation. Such a program might accomplish important environmental and energy goals without serious industry disruption.

The Clean Air Act, passed last year, covers 49 states, and sets tailpipe emission standards, which probably are attainable by the industry, although meeting them will require investments of financial and human capital. California has separate standards that are more severe and, in some instances, require specific responses. For example, the California legislation calls for sale of a small percentage of zero-pollution vehicles by the latter part of this decade. Manufacturers that fail to achieve this will simply be barred from the California market, which accounts for some 20% of the total U.S. market. Rumors persist that GM will meet this demand by offering its Impact electric vehicle by 1996 and Ford is likely to have electric vehicle production two years latter. If these rumors prove true, and such vehicles meet customer expectations, the pressure on Chrysler and import automakers to offer these vehicles may be enormous.

Calls for alternative fuels and appropriate vehicles present serious challenges to the industry. However, the industry, more so than in the past, publicly agrees that overall air pollution must be reduced, particularly in some of our larger cities. The basic and most difficult differences between the industry and public policy makers on this issue appears to be the exact methods and time tables for improving air quality. The industry argues that retiring older, heavily polluting vehicles makes more sense than requiring expensive improvements in new cars, while relying on age and natural attrition to remove the most seriously polluting vehicles from the fleet.

These alternative fueled vehicle programs are initially likely to be small, and therefore provide lower returns than would similar levels of investment in, for example, face-lifting an intermediate vehicle program. However, the regulations set the ground rules for all competitors, and meeting them may determine whether a company can even sell a product in certain markets. Therefore, manufacturers simply must meet them. So an increasing level of regulation on all fronts will probably put smaller manufacturers at a competitive disadvantage unless they can license the various technologies from larger firms at a reasonable cost. Their only alternatives will be to cover regulatory research and development and production costs through price increases or reduced profit margins, and both of those are difficult in a highly competitive market.

To meet the laws of both California and the rest of the states, manufacturers are likely to increase investment in engines, fuel and ignition systems, and emission control systems. There will likely be particular emphasis on research aimed at catalytic converters because most of the remaining emissions are created in the first few minutes of vehicle operation, before today's catalytic converters fully warm-up. Whatever solutions are implemented must be affordable and offer both good operating characteristics and inexpensive maintenance. As with any new regulation, business opportunities exist for some—perhaps engineering service firms and component suppliers—while business risks exist for others—such as smaller manufacturers—o participate in this effort.

Safety challenges will recur throughout the 1990s, and applying basic passenger car standards to light trucks, including recreational, and utility vehicles, will be one of the first major such challenges. About one-third of all light vehicles sold in the U.S. market are light trucks, and two-thirds of these are used primarily for personal transportation, much like a passenger car. Therefore it seems reasonable that passive occupant restraints and other safety features be required on light trucks. Because of structural differences between light trucks and passenger cars, such as vehicle height, this not as easy or inexpensive process as one might expect. As with emissions, this trend offers significant opportunity for internal and independent suppliers, and safety, too, will require careful investment.

Because the light truck has increased market importance, companies like Chrysler are undertaking more frequent product facelifts. These provide the opportunity to incorporate these safety features more routinely and rapidly. Some new vehicles, such as the Chrysler minivan and Ford Explorer sport utility, are equipped with various safety features before regulations demand them.

Safety has become a key marketing feature and some vehicle manufacturers are trying to create product differentiation through safety features. Chrysler has been particularly aggressive in the safety arena, installing airbags rather than passive belts, and focusing significant advertising effort on that decision. If customers value such safety features, they may confer market advantage and permit some price increases to cover their cost. However, it is still unclear how important a factor safety is in the consumer's purchase decision.

The side impact standard, which passed last year, presents the most significant passenger car safety standard initiative. Manufacturers claim only a few vehicles, such as the Lincoln Town Car, and some large European makes, protect occupants when the collision point is on the side and near the front windshield pillar. Some vehicles apparently need only additional interior door panel padding to meet this standard, while others may require complete re-engineering of the door and locking mechanism. However, this is another regulatory area that the vehicle manufacturers question, because they feel that the required engineering talent and capital expenditures could be better spent elsewhere for corporate competitive reasons.

Conclusions

The 1990s will see challenges as competitive and complex to the U.S. automotive industry as those of the 1980s. These challenges will be international in nature, as the Big Three try to capture share in the U.S. and overseas markets. The Japanese motor industry will continue its competitive challenges, from product offerings to quality and cost effectiveness. As companies develop new products to meet market demands and regulatory pressures, cost, quality, and rapidity will be of upmost importance because consumers will be attracted to products that meet their needs in a timely and high-value manner. There is no isolation from change, and these issues will effect every function within the manufacturer, including vehicle development, manufacturing, and sales and service. These changes will almost certainly put a premium on training all levels of the workforce in specific skills as they become important, and upon a high level of workforce flexibility, so that employees at all levels can be rapidly redeployed to the activities dictated by the competitive situation and realities of the moment.

Automotive Product Technology and Worker Training

Part Two: A Series of Product Innovation Implication Memos and Technology Trend Summaries

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by
Michael S. Flynn
David J. Andrea

The Office for the Study of Automotive Transportation
The University of Michigan Transportation Research Institute

for
The American Society for Training and Development
Alexandria, VA

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The Office for the Study of Automotive Transportation
The University of Michigan Transportation Research Institute
2901 Baxter Road
Ann Arbor, MI 48109-2150

Phone: 313-764-5592
Fax: 313-936-1081

The overall objectives of the Office for the Study of Automotive Transportation are to provide information resources, industry analysis, communication forums, and academic research that meet the continually changing needs of the international automotive and automotive-related industries.

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Assembly Systems

General Issues

Many of the product changes affecting the assembly plants—rear wheel drive to front wheel drive and body-on-frame to unitized body—have already been implemented, particularly within Chrysler plants. These product developments fostered changes in areas such as powertrain installation (from a more labor-intensive engine/transmission installation through the hood to an automated lift from below) and body welding operations (from separate body and chassis build to welding of complete side, bottom, and roof within accurate and sophisticated welding fixtures such as "robo-gates").

Some other changes are being implemented to various degrees on a plant-by-plant basis. For example, sequential scheduling of vehicles and inbound parts allows parts to be unloaded from trucks and placed immediately on conveyor lines in the proper order for assembly. Chrysler led the domestic industry in this practice, and that cut work in process inventories significantly. It also created more pressure to stabilize production schedules and increased the complexity of transportation logistics into the plants.

Another significant trend has been the reassignment of quality responsibility throughout the assembly operation, from a centralized inspection system, which is often at the end of the line. This has required installing a quality discipline in all workers and broadened the need for quality-control statistical and graphic skills throughout the workforce. These developments also demand fundamental changes in performance review and reward systems which, again, vary on a plant-to-plant basis.

While these basic changes have appeared in most assembly plants, it is important to monitor the success of and commitment to these concepts in each plant, to evaluate its long-term viability. There are three other emerging issues that manufacturers are pursuing with common strategies, but many variations exist, reflecting the needs of the particular manufacturer and product.

Contiguous Operations

As assembly plants are converted to new product, there is a trend to build on-site, or contiguous, metal stamping, plastic molding, and other vehicle- or platform-associated component operations. The primary advantages of on-site production of body panel and other exposed surface materials is to reduce the distance and number of material handling steps. That should improve quality and reduce the level of work-in-process and thus should reduce operating costs. This trend has increased the number of jobs located within the assembly plants, although the contiguous activities operate as their own departments and may or may not have bumping rights throughout the assembly complex. Assembly plants with recent investments in contiguous stamping and plastic molding capacity (or plants located near virtually dedicated stamping plants, such as Ford Chicago Assembly and Stamping plants) appear to have an advantage for keeping current product(s) or attracting new, replacement product(s). It will be interesting to track the success of Saturn because its contiguous stamping, engine, and transmission capacity may or may not be used as a future model for other assembly complexes.

Modular Assembly

Modular product designs and other design for assembly techniques offer significant potential labor saving advantages. Examples of modules include instrument panels (dash pad, instruments, entertainment systems, etc.), door assemblies (inner and outer panels, interior trims panels, glass, mechanical/electrical controls), front and rear suspensions (cradle, axle, springs, shocks, drive shaft/half shaft, etc.), and front and rear exterior fascia (lamps, grille, bumpers, trim, etc.). By designing and manufacturing these systems in discrete modules, manufacturers attempt to reduce final assembly complexity, improve quality through off-line testing, and reduce final vehicle manufacturing cost.

Modules may be assembled by suppliers (either independent or allied) in separate facilities or assembled "off-line" within the assembly plant. Outsourcing modules poses a significant threat to assembly employment because fully developed modules will be shipped into the assembly plant as "plug in" or "drop in" units. This shortens the final assembly line and permits close station intervals by eliminating the need for much intricate assembly work.

Within the assembly plant, off-line assembly is becoming more prevalent, especially for instrument panels and interior trim components. Such off-line assembly involves teams of employees operating short lines, whether stationary or moving. These teams are typically cross-trained to offer job variety and production scheduling flexibility. Specific job tasks are similar to traditional assembly jobs, but work pace, team involvement, and scope of work may be different. Such changes increase the need for on-going training in specific job-related skills as well as "softer" teamwork and decision-making skills.

Three Shift Operations

Automakers today face an increasing challenge to become more productive in their use of capital assets, just as they must improve the productivity of their human resources. Capital costs for construction, finance charges, and maintenance requirements for plants all involve costs, and must compete for the budgetary dollar. One clear response to this situation is to increase the utilization rate for any given facility, so that these fixed plant costs can be spread over more production units.

Automakers' efforts to increase capacity utilization cover a broad range. They include increasing both plant and workforce flexibility. They also include expanding the production time of the facility through a number of scheduling changes. One such change is the conversion to newer shift schedules that permit expanded operation of the plant. Some of these shift schedules permit normal production for considerably more hours than the 80 hours plus overtime more typical at the Big Three for the past twenty years.

One such approach is the "three-crew, two shift" schedule. This schedule calls for three work crews who staff the plant for a normal two shifts for each of the seven days in a week. This yields 14 shifts a week, and those may range from 8 to 10 hours, or 112 to 140 hours of production a week.

Such approaches clearly require breaking out of the "Monday to Friday, 8 hours a day" limitation that the industry has assumed for many years, and expanding the pay period beyond one week. This will require negotiations to establish "normal" schedules, work that qualifies for shift and overtime pay premiums, and methods of rotating the crews. The gain in efficiency suggests that we will almost certainly see the spread of this system in the future, as the automakers strive to expand production without incurring new capital investments for new facilities. The most recent example of this is the decision of the St. Louis minivan plant to adopt a version of this schedule, providing Chrysler with expanded capacity in that profitable segment, without extensive capital investment.

These approaches will require fewer workers, although most of the labor savings will be in the white-collar, support functions. They will require greater flexibility from the workers, and will increase the importance of the skilled trades in keeping the plant operating. On the other hand, they offer the possibility of increased employment at existing plants, and that can offset future job losses to productivity improvements, and hedge against losses to outsourcing. However, it provides little protection against market share erosion.

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Block	Cast iron. Small percentage of aluminum with emerging new types of processing (eg, lost foam).	• Manufacturability • Cost reduction • Quality • Fuel economy • Performance	• Slight increase in aluminum. • Increased precision machining and casting technology.
Valve Train	Majority configuration: 2-valves per cylinder driven by pushrods via camshaft. More recent designs: overhead cam driving 2- or 4-valves per cylinder.	• Performance • Emission regulation • Fuel economy • Competitive standards/ offerings • Cost reduction	• Increased use of single and double overhead camshaft designs. • Increased use of 3 and 4 valve per cylinder designs. • Introduction of variable control. • Material substitution.
Cylinder Head	Approximately one half cast iron and one half cast aluminum.	• Manufacturability • Fuel economy • Quality • Cost reduction • Performance • Competitive standards	• Aggressive increased use of aluminum. • Redesign to adapt to overhead cam and multivalve engines. • Increased precision machining and casting.
Crankshaft	Cast iron or forged steel.	• Fuel economy • Drivability • Quality (durability)	• Increased use of forged steel. • Increased precision machining.

Engine Subsystem

It appears likely that well over one-half of Chrysler's various engine configurations will experience substantial engineering redesign within the next decade. While no advanced engine types appear likely to completely displace conventional spark-ignited, internal combustion engines over that period, the on-going redesign process may have significant impact on Chrysler engine casting operations, component operations, and machining operations. In particular, these changes may well increase the required level of skill in machining, as well as the relative employment levels in machining. A possibility exists that much of this work will become automated, through reliance on machining centers. In either case, machining will have to meet more rigorous and precise engine design specifications and requirements. Another trend needing careful monitoring is the development of two-stroke engines. Chrysler is keenly interested in this technology and, most likely, will have some low production volume applications. It is difficult to estimate the impact this technology will have given its application is highly dependent upon specific product development programs, capital expenditure plans, and research and development advances. Therefore, this memo will concentrate only on four-cycle internal combustion engine developments.

Block

There has been some suggestion of a trend toward increased use of aluminum blocks by the traditional North American OEMs, but this appears to have moderated recently. Still, aluminum blocks may account for some 5% - 10% of engines by 1995. To a certain extent, how common aluminum blocks become may depend on the further successful development of lost-foam casting techniques. These are being employed in GM's new Saturn facility, and Saturn's success may influence other manufacturers' preferences for engine block material.

A major driver for the increasing use of aluminum blocks is weight reduction, and that in turn is driven by concern for the fuel economy of the vehicle. Concern for fuel economy reflects the price of fuel and/or the level of CAFE standards. At the present time we continue to experience relatively low U.S. gasoline prices and an apparent willingness on the part of the consumer to accept some increased gasoline prices and/or taxes, so the immediate need for weight reduction is fairly low. Other fuel economy strategies could be pursued in place of weight reduction, including increasing the efficiency of the engine/drivetrain through electronic integration of the engine and the transmission. Concern for fuel economy is volatile, and the continuing crisis in the Mideast or raised CAFE standards could rather suddenly make it a major factor again as it was in the 1970s.

Some questions remain regarding the reliability and durability of aluminum blocks and heads, while cast iron block technology is tried, proven, and generally less expensive. Quality and reliability concerns may also be alleviated by the proper design and application of various aluminum alloys. Perhaps most importantly, the Japanese manufacturers seem to be increasingly relying on aluminum, and this market pressure may lessen Detroit's current resistance to aluminum.

It should be noted, however, there exists some difference of opinion within the industry regarding both the technological efficacy and the rate of application of these new technologies. If gasoline prices and/or taxes increase significantly, or if CAFE requirements are increased significantly by federal legislative activity, Chrysler is liable to experience a significant impact on its internal component sources, possibly resulting in a reduction in market share and subsequent job loss.

Valve Train

Valve train configuration is another area that is both legislative and market driven. Chrysler appears to be well positioned with regard to the trend toward 4-valve/cylinder vs. conventional 2-valve/cylinder engines. However, some North American OEMs (e.g. Buick) have decided to retain pushrods in engines rather than rely on the single (SOHC) and dual overhead cam (DOHC) configurations, which are particularly prevalent on Japanese cars. This reappraisal seems to represent a response to consumer-perceived cost benefits and a preference by vehicle manufacturers for product technology complexity reduction if reliability or durability is in question. Currently domestic manufacturer warranty costs appear to be higher for these more complex valve trains, and that may restrict their development. Again, market pressure from the Japanese may overcome this concern.

Cylinder Head/Crankshaft

Cylinder head and crankshafts do not appear likely to experience major redesign. Material substitution, such as aluminum for iron in cylinder heads, appears possible, either due to legislative or market forces. Cylinder head redesign will be required if major valve train redesign is undertaken.

All of these are areas that should be carefully monitored for new technological and manufacturing developments that could affect both future vehicle design and component development.

Valvetrain Subsystem Detail

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Valves	Machined steel alloys.	• Fuel economy • Quality (durabilty) • Clean Air Act • Cost reduction • Performance (Mass reduction)	• Increased use of 3- and 4-valve configurations. • Possible application of advanced ceramic and other materials.
Rocker Arms/Lifters	Stamped or cast steel rocker arms with hydraulic adjustable lifters.	• Cost reduction • Fuel economy (friction, mass reduction) • Quality (reliabilty/ durabilty)	• Increased substitution of over-head cam engines for pushrod configurations. • Increased use of roller lifters.
Pushrods	Machined tube stock.	• Cost reduction • Fuel economy (friction, mass reduction) • Quality (reliabilty/ durabilty)	• Possible application of com-posite materials. • Elimination with application of single and double overhead camshaft designs.
Camshaft	Machined steel bar or cast iron.	• Cost reduction • Packaging • Fuel economy (friction, mass reduction; valve timing) • Quality (durabilty) • Performance	• Possible application of com-posites, hollow tube designs, and powdered metals. • Possible application of variable valve lift/timing.

Valvetrain Detail

As most Chrysler valvetrain components are sourced from outside suppliers, the changes summarized on this matrix will not directly impact Chrysler facilities beyond the issues discussed in the engine memo. It is unlikely that components that require significant manufacturing capital investments will be candidates for insourcing given Chrysler's general restricted access to capital funds. Also, there are well-established suppliers in these component markets (TRW and Eaton among others) and these suppliers tend to have well-established design, engineering, and purchasing customer-supplier relationships.

The engine plants will be affected by increased complexity and requirements for manufacturing precision in valve head assembly. This will demand retraining activities for new engine programs (see attached program timing sheets for likely introduction dates). Retraining may center around different assembly practices or production layouts. Ford Motor has been implementing their concept of "modular" engine families. In this regard, "modular" refers more to a design concept allowing use of common parts and machining lines across a family of displacements (Ford's V-8 family may include displacements from 3.0L to 4.6L) than to a building block concept (bolting two cylinder sections together to get V-4, V-6, or V-8 configurations).

Ford's effort revolves around flexibility and the same will be required of Chrysler. Great uncertainty exists within the market as to whether fuel economy, reliability, durability, and driveability requirements complement or conflict with customer demands and perceptions of quality, value, and innovation. There is a major debate within Detroit's engineering community over whether all engines need to be "high tech" (including multi-valves per cylinder, turbo- or supercharging, overhead camshafts) or if "low tech" (current configurations) are sufficient to meet the above expectations. This indecision is driven by uncertainty about the customer's true concern for these technologies if, in fact, the same performance characteristics may be achieved with a "lower tech" solution. Above all, the guiding forces of quality, dependability, reliability, and performance will dominate decision making. Although quality is an overriding attribute, durability refers to the length of a component's life and reliability refers to the component's continued performance over that life.

Increased manufacturing precision will be required within each of these components. In general, this refers to increased importance of the machined surfaces, allowing a reduction in component mass. For the most part, less precise manufacturing forces over-engineering of components to assure strength, durability, and performance. As manufacturing becomes more precise the need for extra material or dimensional allowances diminishes, thus saving weight and cost. It is imperative that both suppliers and engine plants invest in product and manufacturing design and engineering as well as capital equipment to assure this improvement. General training programs will be required with these product and manufacturing changes—including advances in automation, tool set up, machine line configurations, and maintenance. The drive for flexible manufacturing will certainly require workforce training across skills and departments and likely involve the manufacturing workforce in design and engineering of both product and process.

Electronics Subsystem

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Engine Electrical	Copper wiring harness; 12 volt electrical system with mechanical and electronic engine control.	• Emission regulation • Fuel economy • Consumer-perceived value/service • Performance • Quality • Manufacturability	• Increased use of distributorless ignition systems and coil on plug designs. • Introduction of increased or dual voltage systems (12-24-48 volts). • Gradual increase in multiplex applications.
Fuel Management	High pressure single point and multi-point fuel injection with electronic control.	• Fuel economy • Drivability • Performance • Competitive standards/ offerings • Emission regulation	• Increased application of multi-port fuel injection. • More refined control, possibly increased use of adaptive control for each cylinder.
Chassis Electrical	Copper wiring harness; 12 volt lead-acid battery with engine driven alternator.	• Cost reduction • Quality • Increased application of electronics	• Application of discrete multiplexing (copper wire) systems with ability to integrate into chassis and engine electrical systems. • Increased system operating voltage.
Comfort and Convenience	Audio; electric motor power windows, door locks, seats; lighting; etc.	• Competitive standards/ offerings • Drivability • Safety regulation	• Increased application of electronics, integration of "smart" switches, "fuzzy" logic. • Increased emphasis on non-driver occupants. • Increased option specification by customers.

Electrical/Electronic Subsystem

Engine Electrical

Most analysts agree that new technological features will play an important role in vehicle sales potential. Further, a number of electronic features, primarily powertrain controls and consumer-convenience features, will probably represent important elements of these technical product differentiators. These electronic features, as with other technical features, will have to provide perceived consumer value, either through reduced cost or enhanced benefit.

The significant components of any new engine electrical componentry or control system are the sensors, actuators, and processors. As the complexity of automotive electronics increases, there is growing pressure to find a replacement for existing wiring systems, because current wiring harnesses become cumbersome and create packaging difficulties. The utilization of steering-hub mounted controls, stalk-mounted controls, the electronic integration of engine controls and drivetrain, as well as increased monitoring and diagnostics capability all drive the need for a replacement for conventional copper wire harnesses and switches. Multiplexing, microprocessors, and, perhaps eventually, fiber optics are the likely alternative technologies.

Engine control and fuel management are two prime areas for implementation of these new technologies because they are areas of high system density. As these areas become more integrated and complex, there is a risk that some parts and components may move out to suppliers that are capable of producing the entire subsystem that contains it. Moreover, today's engine wiring harnesses work could all be lost, with outside suppliers picking up the "replacement" work as part of the electronic control system.

The voltage level of passenger vehicles is expected to increase from the current 12 volt level to 24-48 volt levels, although a 12 volt system may be retained in some small electric motors. This would require redesign of a broad range of components, including alternators, voltage regulators, and starters. Product redesign represents a risk, because that is a convenient time to change suppliers.

It is likely that most manufacturers will convert to a distributorless ignition system in the next five to ten years. This is an example of a mechanical control system, currently produced outside of Chrysler, which is being converted to an electronic control system. Because Acustar's Electronics Systems Division engineers and produces a significant portion of the engine electronic control system, it is feasible that Chrysler may recapture, in its electronic form, this engine control component.

Fuel Management

The most significant change seen in fuel management systems is the adoption of multi-port fuel injection. This provides better fuel economy and emission control over current single point systems (the system most prevalent on Chrysler vehicles). Because Chrysler produces no fuel injectors or systems internally this trend will not have a direct impact on Chrysler workers but highlights the need for advancing Chrysler engine design and offerings to remain competitive.

Chassis Electrical

The most significant change likely to occur over the next ten years is the application of discrete multiplexing systems. Most probable application areas are steering columns, doors, instrument panels, and consoles. Each of these areas has a high concentration of wiring with ending points at switches, lamps, gauges, and speakers. As additional convenience features, air bags, and other electronic features are added, packaging becomes difficult and the number of wires and connectors makes both assembly and service difficult. The major effort to solve these problems is the application of multiplexing, the transmission of many signals to a variety of destinations over a single wire (similar to a telephone system). Chrysler is active in the development of industry multiplexing standards and appears likely to keep pace with industry advances.

Electronic- or electric-system service problems are the greatest single customer complaint. Connectors are a major source of these problems and complex diagnostics make return customer visits a common occurrence. Therefore, although multiplexing components may be of a higher purchase price, reduction of assembly and warranty costs and improvement in customer satisfaction may justify the cost.

An interesting product sourcing strategy may develop. All of Chrysler's Acustar wiring harness activities are with the El Paso Automotive Products Division and its associated Mexican plants. With multiplexing systems, the labor content as a percent of total systems cost may be driven low enough to re-source this component back to the United States. Because of the likely high value added and profit of these systems, Chrysler may produce these systems, which appear to be within the capabilities of facilities like Huntsville.

Comfort and Convenience

From advanced audio systems with digital audio tape and compact disk players, heated front windshields, and trip computers, to rear-seat lighted vanity mirrors, electronics are being used to improve driving comfort and convenience in all vehicle segments. Electronics will increasingly be needed to integrate systems (see discussions elsewhere), to reduce complexity (e.g., one micro-processor controlling several different systems), and to allow optimization of function (e.g., an electric front windshield defroster that automatically assists the defrost feature of the heating system). It appears that Chrysler has maintained competitiveness against domestic makes in this area (particularly in full-size segments) but may be a bit behind the Japanese in the compact segments. Chrysler will likely try to remain competitive in this area, but most new features—particularly low volume luxury items—will likely be produced by independent suppliers. A critical point to monitor is Chrysler's internal development activity, because that may be a proxy for possible future Chrysler manufacturing. Again, these systems seem within the capabilities of Huntsville.

Engine Electrical Subsystem Detail

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Engine Wiring Harness	Copper wiring with copper terminals and injected molded connectors; low voltage connecting battery/ alternator; high voltage for coil/ distributor/plugs.	• Quality (dependability/ reliability) • Cost reduction (including warranty) • Increased application of electronics	• No major changes; continued improvements likely in connector materials and designs. • Application of multiplexing in upscale or performance vehicles. • Increased system operating voltage.
Engine Control Module/Related Sensors and Actuators	Printed circuit boards encased in plastic/ composite shell; electronic and electro-mechanical sensors and actuators for input and action.	• Emission/fuel economy regulation • Packaging • Cost reduction • Quality (dependability/ reliability/driveabilty)	• Increased use of distributorless ignition systems. • Redesign of software incorporating advances such as flexible fuels. • Increased diagnostic capabilities. • Increased component integration.
Starter Motor	Electric motor with solenoid to engage drive gear into flywheel; various cast and stamped parts with electric motor components.	• Cost reduction • Quality • Packaging • Quality (dependability/ reliability)	• Material substitution (magnets, case, other components) to improve cranking power while reducing weight and package size.
Alternator	Engine driven alternating current generator; incorporating an electronic regulator to control output and electronic converter to direct current.	• Cost reduction • Packaging • Quality • Fuel economy • Competitive standards (electrical requirements)	• Redesigns to increase capacity to accommodate advances in engine and chassis electrical systems and increased electrical loads.

Engine Electrical Detail

Within the engine electrical subsystem, the greatest amount of Chrysler activity will occur in the engine wiring and the electronic engine control module (ECM), sensors, and actuators area—starter motors and alternators are outsourced and are not likely to be brought into Acustar. External forces, such as fuel economy and emissions regulations, will require engineering changes to the ECM to assure compliance while maintaining competitive vehicle driveability and performance characteristics. Improving dealer service capabilities and diagnostics will be another important driver of product redesign. Overall, these changes are within current Chrysler's Acustar Electronics Division's engineering and design capability—for the most part they involve software changes to the ECM. With the increased integration of electronic components there appears to be insourcing opportunities. However, this electronics insourcing will not result in large employment gains as the integration is likely to occur through the addition of extra chips or actuators that replace mechanical devices. Employment loss in the electro-mechanical and mechanical device companies will likely be larger.

The trend towards distributorless ignitions is an example of the trend from electro-mechanical to pure electronic control. Previous distributor systems had a camshaft driven rotor that made an electrical contact between the coil and the ignition wire harness, sending an electric charge from the coil to the proper spark plug. Distributorless ignition replaces the electro-mechanical distributor with ignition coils that are paired with single or "partnered" cylinders and spark plugs. These individual coils receive a signal from the electronic engine control module which fires the spark plug in the proper sequence. Because Chrysler produces the electronic engine control modules, controls the most sophisticated technology, and provides the greatest value-added, this type of function integration may result in re-sourcing independent contacts to Chrysler.

Likely product innovation in the various sensors and actuators holds a multitude of opportunities and risks. There is opportunity due to the rapid increase in applications and continued efforts to improve reliability and durability. These trends usually provide ready markets to exploit. However, all forms of electronic-related hardware and software product life cycles are unpredictable and usually short, adding pressure to recover R&D and tooling costs. Therefore it may seem that Chrysler is not exploiting some "hot" markets, but actually Chrysler may be wiser to follow companies into these markets. For employees, rapid electronic innovations will force workers to operate on steep learning curves—they will need to quickly master technologies, integrating knowledge into work activities, and then rapidly move onto the next technological ıprovement. Product obsolescence makes the electronics market very transient and adds great ·essure to employees.

Another possible integration into Chrysler's U.S. or Canadian facilities is engine wiring ırnesses from Mexican or other independent suppliers. Some analysts speculate that with the lvent of multiplexing, the value added by these systems will be sufficient to outweigh the labor ıst disadvantages of U.S. sourcing, or that the simplicity of these systems may reduce labor ıst's share of overall product cost to such an extent that chasing low labor cost will be a lower iority. If multiplexing systems do return to Chrysler's U.S. facilitates, these new products will quire training founded on its basic elements: plastic injection molding, electrical connectors, and iring assemblies. The logic controls of these devices are well within Chrysler's current pabilities required for the design, engineering, and manufacturing of engine control modules.

University of Michigan/ASTD Automotive Product Technology Impact Study December 14, 1990		Chassis Electrical Subsystem Detail	
Component	**Current Practice/ Configuration**	**Driving Forces**	**Likely Changes**
Chassis Wiring Harness	Copper wiring with copper terminals and injected molded connectors.	• Quality • Cost reduction (including warranty) • Manufacturability • Increased application of electronics • Packaging	• Possible application of discrete multiplexing (copper wire) systems with ability to integrate various systems. • Increase of system voltage. • Wire down-gauging. • Modular designs.
Lamps	12 volt single and dual filament bulbs with various gas charges and base configurations.	• Quality (durability) • Increased application of electronics (electrical loads) • Competitive standards/ offerings (styling)	• Increased use of single lamp sources with fiber optics/light bars for interior lighting. • Possible redesigns for voltage increase. • Innovative colors, backlighting, and styles for interior/exterior.
Battery	Conventional lead plate with acid-based conductive fuild contained in a plastic case.	• Increased application of electronics (electrical loads) • Competitive standards/ features • Packaging (size and weight)	• Possible redesigns for increased voltage or dual voltages. • Incorporation of convenience features (dead battery reserve). • Possible application of dual batteries for high load vehicles.
Fuses, switches, etc.	Switches: various posititive contact, rotary, pressure, and other configurations; fuses: circuit breakers, fusable links, and others; various other electrical hardware.	• Increased application of electronics • Quality (durability/ reliability) • Competitive standards/ offerings	• Increased use with more driver control over vehicle operating parameters. • Innovative styles and designs.

Chassis Electrical Subsystem

Because Chrysler directly manufactures only wiring harnesses, the likely changes in most chassis electrical components will be of interest primarily from the standpoint of the competitive offering of the entire vehicle, and not of the discrete component. In this subsystem, two possible technology developments, multiplexing and higher or dual voltage systems, hold the most significant potential for product change. We will discuss multiplexing in this memo because of Chrysler's production of wiring harness and this technology's direct implications for that product. There will also be a great deal of engineering activity and product innovation if automotive standards shift to higher voltages than today's 12-volt direct current. This may occur to improve the availability of power and to satisfy the power demands for electrically-run body systems and comfort/convenience items. If automotive systems remain 12-volt, only evolutionary improvements will likely be made. Any change away from 12-volt will require re-engineering many of Chrysler's electrical and electronic components, although it is unclear how manufacturing might change to meet the 12-, 24-, or 48-volt products.

Chassis Wiring Harness

The next ten years will see the application of discrete multiplexed wiring harnesses. These systems will initially begin in the steering column, door panel, and perhaps instrument panel—locations where many switches and actuators are located and bundles of wires and connectors make assembly and diagnostics difficult. In turn, these systems will tie into the traditional bundled wiring harness. As issues of dependability, reliability, manufacturability, warranty costs, and others are resolved, multiplexed wiring harnesses will become attractive for entire chassis applications.

Multiplexing operates similar to a telephone line: a single wire transmits many messages or power to a variety of sensors, actuators, power sources, or processors, rather than relying on one dedicated wire routed from, for example, each switch to each motor or lamp. Through an electronic processor, each message or unit of power is given the address of an electric motor or sensor. As that message travels along the single wire—or bus line—it identifies each component along the wire until it arrives at the right address and the appropriate action occurs.

Electrical problems are a significant source of manufacturers' warranty claims and consumer complaints. Many of these problems are associated with the wiring harness and its connectors. The drive to simplify this product, the "nervous system" of a vehicle's electrical system, at the same time that vehicle electronic applications are increasing is a difficult challenge. Multiplexing simplifies the physical structure of the wiring harness—there is only one wire per node—while it complicates the electronic structure—these systems require additional central processing units.

The future manufacturing location of multiplexed wiring harnesses is yet to be determined. Because of high labor content, GM, Ford, and Chrysler have gradually moved almost all harness production to Mexico. Some argue that system simplification reduces the direct labor costs sufficiently to reconsider U.S. production. This may certainly be the case if Job Bank requirements force additional component work in U.S. plants. Some argue that multiplexed systems require a greater amount of electronic sophistication, and this provides another incentive to relocate to the U.S. This second argument is less persuasive since multiplexed systems involve fewer physical components. They do require increased attention to quality and consistency of assembly. However, these two elements are designed into the best systems, and at least some Mexican companies and communities have demonstrated capabilities in these areas.

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Comfort/Convenience Electrical Subsystem Detail

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Audio	Transitorized AM/FM with electronic tuning; cassette mechanism; compact disc player; standard audio speakers with optional upgrades.	• Competitive standards/ offerings • Quality • Manufacturability	• Increased upscale offerings and penetration throughout product line; greater system power. • Offering of digital audio tape. • Increased use of remote chassis.
Instrumentation Gauges and Controls	Analog displays with mechanical or electronic input; electronic LED, electroflorescence, liquid crystal digital displays; miniature lamps; switches.	• Drivability/human factors • Competitive standards/ offerings • Quality (diagnostics) • Safety	• Increased use of mixed analog/ electronic displays; innovative backlighting/highlighting; head-up displays. • Increased use of multi-functional modules with logic. • Multiplexing applications.
Electric motors	Standard copper winding/ magnet arrangement for power seats, window regulators, mirrors, antenna, and other accessories.	• Performance • Competitive standards/ offerings • Cost reduction • Packaging • Quality	• Increased use of alternative magnetic materials. • Application of logic with smart switches and multiplexing. • General increased usage due to functional requirements.
Cruise control	Electronic with mechanical and vacuum control assistance; contact switches.	• Drivability • Cost reduction • Packaging • Quality	• Continued integration into engine control module/traction control systems. • Elimination of non-electronic sensors and actuators. • Possible integration with drive-by-wire.

Comfort/Convenience Electrical Subsystem

It appears that Chrysler's Acustar operation is well positioned within the comfort/convenience electrical subsystem components. These components tend to be high value-added and profitable for each of the vehicle producers' internal component divisions. Within Acustar, automotive entertainment systems accounts for 6% (the fifth largest concentration of 1988 sales by component) of sales and instrumentation and electronic feature products accounts for an additional 4%. With the exception of cruise control, as it is currently configured, each of these components will likely experience sales growth above inflation rates as consumers' expectations rise and component content value increases. Cruise control's growth as a vehicle feature will likely continue, however, it will likely be completely integrated into the engine ignition and fuel injection control systems. Given the competitiveness and capital investment required, it is likely that electric motors will remain sourced to outside suppliers.

Audio

Chrysler offers a competitive line of base and upscale (in association with Infinity) audio options. Electronically tuned AM/FM stereos with at least two speakers are standard across all domestic makes. The cassette feature is found in over 62% (1989 model year) of all U.S.-built vehicles. Compact disc players are increasingly finding their way into vehicles (Chrysler offers CD players in most vehicles above entry level segments for $450). Only about 1% of U.S.-built vehicles are being built with CDs; however, prices have remained relatively constant (if not dropping slightly) over the last few model years; model offerings have increased; and some radios are eliminating the cassette deck, offering only AM/FM/CD. It is likely that with each new interior facelift the ability to offer a CD option will be a major consideration.

Packaging remains a major issue and prevents many vehicles from offering CD or other upscale audio features such as six or eight speakers and subwoofers. Packaging issues force the desirability for a remote radio chassis (where the main components are located under a seat or in the trunk, leaving only the controls to be flushed-mounted). As underdash areas become more compact and door panels thinner (allowing more interior space), wiring, duct work, trim, instrumentation, etc. all begin to fight for the same limited area.

As with many other areas, competitive offerings will remain a major driver. This may force Chrysler to develop other radio options (such as digital audio tape); however, these limited volume options are likely to be developed by outside suppliers, and thus, should not compete for scarce Chrysler engineering and capital resources allocated to more competitive-related powertrain electronics.

Packaging constraints will force the integration of electronics and thus will result in new circuit board and chip designs. As with all interior-freshenings, plastic moldings, bezels, and associated parts will be re-designed. These redesigns may be more frequent with smaller lot sizes.

Instrumentation

Many aesthetic- and human factor-related changes are likely to occur over the next ten years. These will usually be associated with new platforms and major facelifts, but may also be off-year introductions to keep vehicles fresh against competition. This will force the need for innovative product designs and flexible manufacturing systems that will allow more frequent changes with cost containment. Customer perceived value will drive change. Interior designers developed many forms of electronic dashboards, talking warning displays, video displays/controls, and other instrumentation or control layouts which were not well accepted by customers.

Modular design, manufacturing, and sourcing of instrument panels (IP) will likely dominate. Most Japanese transplant facilities build-up IPs off-line in small groups. Saturn workers use robotic assistance to install a complete IP through the windshield. Increasingly companies such as United Technologies, Rockwell, and others promote themselves as "full-systems" suppliers, capable of integrating design, engineering, and sourcing of various components to deliver a complete system. Acustar's component coverage, from mechanical and electronic clusters to climate control and plastic injection molding, will have to continue to compete with independent suppliers for new contracts, since each new interior program will be competitively bid.

This integration of individual parts into modules may result in a reapportioning of component manufacturing. Two scenarios may develop. First, individual component plants may continue to ship components into the assembly plants where off-line IP assembly takes place. Second, components plants may become completely integrated, assembling and testing the entire IP for shipment into the assembly plant. Capital investment requirements will be a prime consideration determining which path Chrysler follows.

Cruise Control

Components that Acustar produces for cruise control systems are likely to be integrated into drive-by-wire systems where the accelerator control is controlled by an electric wire rather than a mechanical connection between the accelerator peddle and the electronic fuel injector controls. This type of integration will likely result in Chrysler production; however, the electronic components will be high value-added (chips, sensors, and software) and will not likely result in the transfer of current levels of employment from independent, higher labor-content, mechanical component producers to Acustar Huntsville Electronics Division.

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Transaxle Subsystem

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Transmission Case	Cast aluminum.	• Manufacturability • Fuel economy • Cost reduction	• Advanced designs to allow packaging of more gear set ranges in confined space. • Advanced machining to reduce weight and scrap. • Some material substitution.
Gear Sets	Machined steel bar stock.	• Fuel economy • Competitive standards/offerings • Quality (durability)	• Additional gear ranges (auto: 4 to 5 speeds; manual: 5 to 6 speeds). • Application of greater precision machining. • Some material substitution. • Increased electronic control (automatics).
Torque Converter	Hydraulic with electronic lock-up feature.	• Fuel economy • Drivability • Cost reduction	• Increased and more effective electronic integration. • Likely reduction of volume if manual transmission grows in overall mix.
CV Joint Assemblies	Ball bearings with stamped steel races and rubber boots with steel half-shafts.	• Quality • Performance • Cost reduction	• No major changes (particularly at Chrysler). • Within industry, rear wheel drive continues to shift to front wheel drive (Chrysler passenger cars already there).

ansaxle Subsystem

It seems that over the next ten years there will be no major product technology changes that l dramatically alter today's automatic or manual transaxle, and in turn, substantially affect these nufacturing facilities.[1] To the best of our knowledge, three major external business ironment issues need to be monitored to assess likely changes in Chrysler's transaxle activities.

:l Economy Legislation

Current legislation requires passenger car fleets to average 27.5 mpg, and light trucks 22 ;. Legislation proposing to increase passenger car fleet averages 20% by 1995, and an itional 40% by 2000, was defeated the week of October 1. This legislation will come before gress again in 1991.

If fuel economy legislation requires dramatic increases in passenger car fuel economy ›ve 30 mpg by 1995, and 32 to 34 mpg by 2000) various corporate responses may develop. t, to improve the overall fleet average, certain lower mileage vehicles (Imperial and New ‹er) may face elimination or drastic reductions in available volumes. This, in turn, reduces the ber of needed transaxles and associated parts. Chrysler may end up selling more smaller cles, but this scenario creates risks of possible plant production consolidation and material irement reductions (smaller car transmissions tend to use less material overall, and more ual transaxles that require fewer parts). Second, this may push Chrysler to redesign existing ;axles which may affect current product line-up. Initially, this may involve some material titution to reduce weight, but to address fuel economy fundamentally, electronic controls must ıcorporated, and entirely new transaxle designs offered. Product redesign is discussed :ately below because it may be driven by legislation or competitive positioning requirements.

ıpetitive Offerings/Transaxle Redesigns

For the most part, future product design changes should not affect employment levels if sler maintains a steady flow of new product capital investment. Some components may be at but overall, employment security depends upon advancements of current designs and ıfacturing processes. In general, worker skills and knowledge levels will need to improve to pace with advances in production and quality control and machining operations—practices quipment known today, but effectively implemented only in best-in-class facilities.

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memo addresses Chrysler's front wheel drive passenger car offerings. For the most part, opinions expressed ıply to Chrysler's rear wheel drive truck transmissions and four wheel drive transfer cases, but individual :t lines need to be addressed separately for complete accuracy.

For example, the introduction and integration of electronic controls in automatic transaxles has been occurring over a period of time—particularly in Chrysler's large automatic transaxles—improving driveability (smoothness of shifts), performance (allowing integration of engine and transmission control), and fuel economy (adapting shift patterns to driving needs). While Chrysler's large automatic transaxle is competitive along these dimensions with foreign and other domestic offerings, without a steady flow of electronic control into smaller transaxles Chrysler may find itself behind its competition. If fuel legislation requirements jump dramatically, Chrysler may find itself needing to outsource transmissions to obtain the most current fuel-efficient designs. This may be a stop gap strategy: if legislation is passed in spring of 1991 requiring 1995 model year vehicles (typically introduced fall 1994) to achieve 33 mpg, Chrysler may need an outside source until internal production may be designed, engineered, and tooled (three to five years for a complete new transmission program). This may result in temporary employment reductions subject to Chrysler's transmission program planning cycles.

Another area of product design concern—which may be driven by fuel economy pressures or competitive offerings—is the introduction of six-speed manual and five-speed automatic transaxles (currently Chrysler offers manual five-speeds and automatic three- and four-speeds). It appears the Japanese are leading this innovation, just as they exclusively offered four-speed automatic transaxles for several model years before domestic offerings appeared. Should fuel economy requirements sharply rise, the ability to offer these transmissions would greatly enhance a manufacturer's ability to meet the regulatory environment. Even if fuel economy standards remain relatively stable, competitors may offer these transmissions and Chrysler's products may then be seen as less innovative and vehicle sales may be lost.

One additional transmission design change that may occur—although, to the best of our knowledge is not being considered for current Chrysler vehicles—is the continuously variable transmission (CVT). This transmission uses two cone-shaped gears connected by a steel or rubber belt to changes the gear ratios (somewhat like the gear cones on a ten-speed bike). The CVT requires many fewer parts. Current applications of the CVT are in European mini-cars (Fiat and Ford) and Japanese minis (Subaru offers a CVT in the U.S. Justy model). This technology should be monitored, particularly if Chrysler links up with a European firm, but over the next ten years it is unlikely to appear in a domestically-produced Chrysler.

Chrysler International Strategies

Although this is outside the pure product-technology area, possible Chrysler efforts with Renault, Peugeot, or Fiat may place some facilities at risk. For example, a Chrysler-Fiat link may result in further losses of Chrysler small car involvement and/or U.S. production. As mentioned above, a foreign joint venture may provide Chrysler technology not currently being internally developed, and thus, not likely to be U.S.-manufactured. This area should be monitored for impact at the vehicle level as well as the component level.

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Steering Gear/Box and Power Steering Pump	Cast iron or aluminum housing with machined rack and attached machined steel tie rod end and bushings; engine driven hydraulic assist pump; plumbing.	• Quality • Drivability (handling) • Fuel economy • Safety • Packaging	• Possible material substitution for weight reduction. • Improved pump designs for improved efficiency. • Introduction of electric motor pump assist/electronic control.
Rear Suspension/Axle	Various styles including independent suspension (stamped steel control arms), non-independent suspension, and coil and leaf springs (steel and composite).	• Drivability (ride) • Cost reduction • Quality • Packaging • Safety (structural integrity)	• Modest changes on high volume units; possible introduction of active suspension on performance or luxury models. • Some use of rear active steering.
Steering Column/ Wheel	Machined pinion gear (mating to steering box rack) attached to a fabricated steel column, typically incorpating a tilt mechanism; plastic molded wheel and hub; entire system energy absorbing	• Safety regulation • Quality • Cost reduction • Packaging	• Application of air bags in light truck vehicles. • Increased application of tilt mechanism.
Front Suspension	Lower control arms: stamped steel; stablizer bars: steel bar stock; hardware: various steel coil springs; struts; rubber bushings; McPherson strut/shock assemblies.	• Drivability (handling) • Manufacturability • Packaging • Cost reduction • Safety (structural integrity)	• No significant changes on high volume units; possible introduction of active suspension on performance or luxury models and multi-link designs.

Steering and Suspension Subsystem

Continual improvements in steering and suspension system designs will provide competitive pressure on vehicle manufacturers to update systems in an effort to provide best-in-segment ride, handling, and driveability characteristics. These three aspects of product quality will drive innovation and new engineering programs for new Chrysler vehicle platform applications. However, it must be noted that new Chrysler steering and suspension programs, as well as engineering changes to existing part numbers, will be constrained by levels of available capital and estimated final consumer prices. Chrysler will be stretching every available resource over the next five years to launch new Jeep products, as well as the LX and LH passenger car platforms. Also, for the most part, Chrysler's product is targeted towards the middle of the compact, intermediate, and full/near-luxury segments—segments which tend to be very price-sensitive and less willing to accept new technology without clear associated value. Therefore, we do not expect the same range of significant technology, sourcing, or material changes to affect the workforce at Chrysler that might occur at other vehicle manufacturers.

There are three areas that require monitoring. First, total Chrysler passenger car and truck sales and the success of efforts to market to non-Chrysler accounts. Second, the rate of continuous design improvement across segments and the ability of Chrysler engineering to compete in the areas of driveability, handling, and ride. Ford, Honda, and Toyota are the primary competitors in the areas of driveability, handling, and ride in small and intermediate class segments, and increasingly, GM in the intermediate and large segments. Third, the rate of cost reduction and consumer acceptance for the two most significant technology changes: electric-motor-assist steering and active suspension.

Competitive Offerings

Although some questions remain, it appears that the American customer is becoming accustomed to more responsive handling characteristics—tauter rides, less cornering roll, and greater steering wheel feedback. This is evident in the wide acceptance of the intermediate Ford Taurus—especially the wagon, which gives handling characteristics never before enjoyed in a family wagon. This more responsive "feel" is likely to be required by future customers who will be more sophisticated and educated through wider driving experiences of foreign and domestic models and the proliferation of media test sources (newspapers, buff magazines, and Consumer Reports-type journals). Therefore, it is imperative that Chrysler keep pace with competitive design upgrades. As argued in other component system memos, competitive designs and value are the front line in maintaining market share which, in turn, protects production and employment.

A strong proxy of Acustar's competitiveness—product quality and innovation, total cost, and customer-required service—is the expansion of outside sales. If Acustar is seriously pursuing and winning contracts for tilt- and non-tilt steering columns, front suspension components, steering arms, ball joints, wheel knuckles, and other components within this system, then Acustar is competitive in this market and management is pursuing a strategy to limit its dependence on one customer. Since continued productivity improvements are likely, sales expansion is an important hedge to maintain employment levels. Tremendous external competition makes this difficult.

Product Technology Changes

New technologies such as electric-motor-assist steering and active suspension will be integrated into vehicles over the next ten years. Most likely these technologies will be applied to limited-production, high-performance vehicles (Stealth RT or Viper) or upper-end near-luxury vehicles (Imperial). Although the unit volumes of these particular technologies will be low—and, likely, result in engineering and production at non-allied suppliers—these technologies are important for an immediate halo effect on Chrysler products and long-term experience base for eventual application on larger volume models.

Electric-motor assist for the power steering pump is desirable for two reasons. First, eliminating the engine-driven pump reduces engine load, thus improving fuel economy. Second, as engine compartments become more compact, packaging the engine, transaxle, and other components becomes troublesome. An electric pump increases the flexibility of where engineers may place the pump, eliminating the strict requirement that an engine-driven pump be located on the engine's front side.

TRW, Allied-Signal, and other component companies have shown operating models of electric pump steering systems. Because the electric pump replaces only the engine driven pump there does not appear to be any significant impact on current Chrysler component production or employment—we do not know of current power-steering pump or electric motor production within Chrysler. This technology is seen as a stepping stone to a full "steer-by-wire" system where the steering column shaft is replaced by wires connecting the steering wheel to an electric motor directly driving the steering system rack. This technology will affect the design of the steering column and, thus, Acustar's tilt- and non-tilt steering column product. We know of no Chrysler contracts for drive-by-wire systems over the next five years. If vehicle applications do develop, volumes are likely to be too low to justify Chrysler production investment and thus will result in outside contracts. This would result in a substitution, to an extent, of outside production for Chrysler production of the current steering column.

Active suspension systems use a variety of methods from adjustable shocks through full-fledged hydraulic systems, which completely replace springs and shock absorber struts. Chrysler offers passive, driver-controlled systems on a variety of its performance cars. As best we know, all these are produced outside of Chrysler. A variety of hybrid systems are being developed by Lotus, Monroe, Gabriel, and others. Due to the integrated nature of suspension systems into the vehicle's structural integrity, safety, handling, and ride performance, Chrysler will most likely retain significant product-engineering interface with its supply base. As with steer-by-wire, significant Chrysler manufacturing employment is not likely given limited volume expectations and capital resource limitations.

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Component	**Current Practice/ Configuration**	**Driving Forces**	**Likely Changes**
Body Panels/Under-body Structure	Predominately steel panels, with some application of plastic (sheet molded compound and injection molding) and aluminum stampings.	• Manufacturability • Fuel economy (weight) • Competitive standards • Quality • Cost reduction • Safety (structure integrity)	• Material substitution, resulting in hybrid material vehicles; particularly plastic for vertical, non-load bearing panels (hoods); some aluminum and composites. • Introduction of various paint systems. • New design procedures.
Bumper Assemblies	Plastic, steel, or aluminum beam supported by plastic honeycomb or hydraulic shock absorbing structure, and covered with plastic facia, plated steel or aluminum bumper.	• Fuel economy (weight) • Safety regulation • Competitive standards/ offerings • Quality (damagability) • Cost reduction	• Redesign to meet likely corner barrier test on passenger car and increased light truck stand-ards. • Material/design changes for weight reduction. • Component integration.
Glass	Laminated safety glass formed by the float process and fabricated into various sizes, dimensions, and curvatures.	• Competitive standards/ offerings (style and features) • Clean Air Act • Fuel economy • Heat/sun loads	• Integration of heating element, antenna, theft detection into var-ious windows. • Reduced thickness. • Improved tinting and use of photochromic properties to manage sun load.
Small Stampings	Steel stampings.	• Fuel economy • Manufacturability (design for assembly) • Quality • Cost reduction	• Integration of parts to eliminate part count, reduce NVH. • Material substitution. • New design procedures.

Body Structure Subsystem

Acustar produces products in each of the bodystructure subsystem categories. Chrysler is likely to remain in these various areas because the bodystructure system components provide structural integrity to the vehicle and thus are a major contributor to vehicle quality, dynamics, performance, and, certainly, safety issues. Flexibility in material design, engineering, processing, and manufacturing capabilities will assure that suppliers are able to meet a wide range of external environmental factors, including CAFE regulation, fuel prices and demands for reduction in mass; recycling laws, customer acceptance and plastic substitution; and CFC elimination, styling forces, and window glass usage. These forces are pulling material selection decision makers in a variety of directions. One point is clear: decision makers will attempt to postpone material, process, and production site decisions until the last possible moment to assure proper analysis and optimization of regulatory, competitive, market, and internal constraints. This will place a premium on manufacturing flexibility.

Body Panels

Reduction of mass without downsizing is again a major goal within product planning staffs. The extent of this push will not be clear until revisions to the corporate fuel economy regulation are considered in the spring of 1991. Legislation considered in the Fall of 1990 would have forced fleet averages to 40 mpg for the 2001 model year. Both domestic and import manufacturers resisted this bill, resulting in its defeat. A fleet average of 40 mpg—given constraints of current technology, manufacturing capability, and vehicle price—would result in a fleet mix composed of a majority of subcompacts and compact vehicles, as well as significant material substitution (aluminum and plastic for steel). Although the final form of legislation is yet to be determined, industry proponents will likely push for CAFE improvements from the current passenger car standard of 27.5 mpg to 29-30 mpg by 1995, and to 32-33 mpg by 2000. The Middle East crisis is certainly another factor influencing the legislative outcome. A resolution of this situation will likely temper Congress's attempt to radically increase CAFE fleet averages.

Ford is pushing the hardest in substituting aluminum for steel in hood and deck lid panels. This is because they have the lowest CAFE fleet average of the Big Three and face significant penalties ($5 per vehicle sold for each 0.1 MPG the manufacturer falls below the standard). Chrysler is in the best position for both passenger cars and light trucks; however, this may change if fuel prices drop rapidly with progress in the Middle East, and if market forces increase the demand for vehicles with the characteristics other than fuel economy. Chrysler is likely to face similar pressures and stamping plants should be prepared to process aluminum.

Plastic panel usage will be driven by CAFE, styling, and even consumer demand. To the best of our knowledge, however, future Chrysler programs (LH and LX) will predominantly use steel panels. Chrysler may be able to slowly add plastic panels to its current capacity (for example, adding plastic fenders to a current steel paneled vehicle, resulting in a "hybrid" vehicle), but typically the Big Three have used independent suppliers (GenCorp, Budd, and others) for complete plastic programs. As with material change to aluminum, a switch to plastic will require design, engineering, and testing to assure structural integrity and federal crash standard certification.

Stationary emission regulations are another area important to monitor. This may drive assembly plant paint systems to water-based paints or other systems that dramatically reduce the level of solvents used in the painting process. Capital investment will likely occur in the various assembly plants as new programs are introduced for paint operations that have not already been updated.

There are a few new experimental stamping processes that should be monitored. The most radical is a one-die process that forms the sheet metal by pressing it against a body of water. The water conforms to the top die and forms the shape of what traditionally would be a second die. This process significantly reduces die cost, but increases process cycle time because the "hits" cannot be as rapid and the metal must be dried. Current use is limited to prototypes. Some Japanese manufacturers, however, are trying to achieve production-rate processes.

Bumper Assemblies

There will be constant pressure to reduce weight, improve resistance to damageability, and maintain current safety standards. These pressures will likely result in material changes and possible redesigns of internal components. However, as best we know, there are no major changes on the horizon that Chrysler's current capabilities cannot meet. If anything, these capabilities are likely to be in demand as passenger car standards are applied to light trucks.

Glass

Glass amounted to 6% of Acustar's 1988 sales, equal to transaxles and transmissions, entertainment systems, and wiring harnesses. Chrysler's recent $37 million investment indicates a commitment to this business. This appears to be a business that Chrysler will keep if it continues to earn reasonable returns. Just as Ford sold its steel division but kept its glass division (and actually expanded it by entering into a joint-venture with a Japanese firm), the Big Three are likely to keep diversified activities given, Job Bank requirements and a reasonable rate of return. In general, there will be pressure to reduce the thickness of the glass (to save weight) and increase the ability to fabricate into more complex shapes (for styling). These factors will demand a more controlled process with improved quality control activities.

Small Stampings

As with other components, there will be continued pressure to reduce the thickness and size of small stampings to save weight and material cost. The complete elimination of some engine accessory mounting brackets and other similar stampings might be one possible employment threat. In a drive to reduce noise, vibration, and harshness (NVH), new engine designs (e.g., Ford's 4.6 L V8) mount air conditioning compressors, alternators, and air pumps directly onto the engine block. This eliminates fasteners and brackets that can vibrate and produce noise.

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Seats/Interior & Exterior Trim Subsystem

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Seats	Metal frame with urethane cushions covered with fabric or leather.	• Competitive standards/ offerings • Drivability (ride/comfort) • Safety regulation • Manufacturability • Packaging • Cost reduction	• Focus on ergonomics with advanced cushion design, additional mechanical/electric adjustments. • Integration of seat belt into seat module. • Frame material substitution.
Instrument Panel	Vinyl and other synthetic material trim covering urethane shell.	• Safety regulation • Competitive standards/ offerings (style) • Quality • Cost reduction	• Redesign for passenger air bag (pass car) and driver/passenger air bag (light truck). • Focus on ergonomics for instrumentation and HVAC. • Introduction of new cover and structural materials.
Headliner/Carpeting Doorpanel Trim	Synthetic fiber with hardboard, preformed backing (headliner) or flexible, precut sections (carpeting).	• Manufacturability • Cost reduction • Quality • Packaging	• Integration of accessories for modular assembly (headliner). • Increased focus on fashion. • Increased focus on ease of assembly.
Exterior Trim	Variety of materials and processes including rubber extrusion (bodyside moldings), zinc diecastings (emblems, bezels), plastic injection moldings (grilles, lamp lens), and aluminum.	• Quality (of part and protection of body) • Cost reduction • Fuel economy • Competitive offerings (styling)	• Substituion to lighter materials. • Redesigns to promote aerodynamics. • Continued integration into body (modular windows). • Use of graphics for fashion.

Seats/Interior and Exterior Trim Subsystem

Chrysler-produced products within this subsystem include instrument panels; interior consoles; door-trim panels; interior moldings; seat covers; arm rests; head rests; and plastic molded pieces including small body-panel pieces, fan shrouds, and tail-lamp lens assemblies. Vehicle manufacturers generally do not view these products as "core" components providing vehicle integrity, structural properties, or key competitive differentiation. Therefore, these products generally are on a potential outsourcing list. It is our best estimate that within this subsystem the supplier's ability to meet competitive styling and value offerings, within the ever-present umbrella of cost competitiveness and quality improvements, will drive sourcing decisions. Because of Chrysler's involvement throughout each of this subsystem's components, the general trend for internal and independent suppliers to sell "full-system" capabilities, and Chrysler's job security and Job Bank situation, production throughout this subsystem may be protected.

Seats

Chrysler only makes seat covers for this subsystem, so is less likely to face direct competitive challenges or work content changes due to product-design innovation (such as integration of the occupant restraint belt into the seat structure). However, a direct challenge will come from the independent seat suppliers, such as Lear Siegler or Johnson Control, who position themselves to supply seats to the assembly plants fully built-up and in sequence to assembly schedules. Additionally, foam-in-place seat production involves the injection of urethane foam directly into a mold that has been lined with the seat covering. This completely replaces the cut-and-sew operations producing seat covers for installation onto seat frames built-up within the assembly plants or within captive supplier facilities. Both these trends place Chrysler's seat cover employment at significant risk.

Instrument Panels

This product is likely to receive continued investment as Chrysler extends air bag installations to the passenger side. This change, plus the continued focus on ergonomics, may result in more frequent design changes in passenger cars. The light truck market will see new designs as passive restraint legislation, which Chrysler will probably meet through air bag installation, covers this segment. Another overall trend is to build up complete instrument panels and perform off-line testing at the assembly plant.

These changes will most likely require increased levels of near-continuous training for new product lines. The trend towards modularity will require cross-training of employees to enable the workforce to know how to build complete instrument panel assemblies. Pressures to contain costs will force the examination of automation and new production flows or work organization. This, in turn, will require training effort on the "softer" issues of quality control, teamwork, and decision-making.

Headliner/Door Panels/Carpeting

Modularity is a major driving force for these products. Overhead consoles, map lights, visors, and assist straps are being produced together to ease final vehicle assembly and improve quality through off-line build and testing. Door panels may be shipped complete into an assembly plant, with arm rests, control switches, carpeted kick panels, and audio speakers installed. As with instrument panels, this results in more complicated component assembly, probably requiring cross-training of smaller work groups. In the future, these products may also be redesigned more often, as interior design receives increased attention and emphasis from an ergonomics standpoint and as an important fashion element. Beyond the ever-present pressures for improved quality, production cost, and design packaging, we know of no significant product or manufacturing process innovation that is likely to require a radical departure from a plan of continuous training to improve overall worker skills.

Exterior Trim

As with the other trim areas, there is likely to be a continued shift to lighter materials (plastics for remaining die cast moldings, bezels, etc.) and redesigns for improved aerodynamics and styling-related differentiation. Chrysler appears to have positioned itself well, with significant investment in injection molding and CAD/CAM capabilities. There are many independent suppliers in this segment, including recent Japanese transplants. This is likely to increase competition for Chrysler captive supplier plants, and thus pressure for productivity and quality improvements.

HVAC Subsystem

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Air Conditioning Compressor	Die cast aluminum body with internal pistons and electromagnetic clutch using R-12 Freon for refrigerant.	• Clean Air Act • Fuel economy • Competitive standards/ offerings	• Redesign to incorporate change of refrigerant. • Redesign to lighten unit and reduce size for better under hood packaging.
Radiator	Copper or aluminum tubes surrounded by copper or aluminum fins with plastic blow molded end tanks.	• Fuel economy • Competitive standards/ offerings • Packaging	• Continued change towards aluminum; continued redesigns to meet front facia (styling) changes and engine heat management requirements.
Heater Core/ Condensor/ Evaporator	Copper or aluminum tubes surrounded by copper or aluminum fins; heater core contained within a plastic molded housing for air direction and temperature control.	• Clean Air Act • Fuel economy • Competitive standards/ offerings	• Redesign to incorporate change of refrigerant (condensor/ evaporator). • Redesign to lighten unit and reduce size for better under hood packaging.
Engine Fan	Electric motor with plastic molded fins (front wheel drive) or engine driven blades through a thermostatic-controlled clutch.	• Quality (noise) • Cost reduction • Fuel economy • Packaging	• Increased use of electric motor driven fans and multiple units per vehicle.

Heating, Ventilation, and Air Conditioning Subsystem

The most significant upcoming change within the heating, ventilation, and air conditioning system will be the regulatory elimination of Freon in an effort to reduce chlorofluorocarbon emissions to protect the earth's ozone layer. The industry is searching for a suitable gas replacement that will allow the efficient transfer of heat from the occupant compartment to the environment. The industry is in a difficult position, facing evolving regulatory pressures and the need to satisfy the conflicting engineering pressures of using replacement gases with lower efficiencies than Freon: larger radiators and condensers to effectively remove heat from interior compartments and reduction of the front end's surface area to improve aerodynamics and reduce vehicle weight. For the most part, known Freon replacements (currently HFC or hydroflurocarbon is the leading substitute) are much less efficient. However, recent R&D innovation in the compressor and related components indicates that HFCs may go far beyond being simply a transition solution—improvements in the mechanical area may make up for the lower efficiency of the heat transfer medium.

While the corporate engineering and design functions will face tremendous challenges from this environmental effort, it is certain that customers will demand air conditioning systems—that is a given. Chrysler has phased out some AC compressor production to the Michigan Compressor Company, a joint venture between Toyota and Nippondenso. Therefore, production and employment effects of the Freon replacement and subsequent compressor and system changes may have more effect on outside suppliers. Chrysler assembly workers will face a more complicated and precise assembly procedure as refrigerant leaks in the assembly process and on-board after assembly come under greater regulatory scrutiny.

It appears Chrysler has begun to put in place the needed aluminum brazing and fluxing technologies in response to the industry's general trend towards lighter weight aluminum core/plastic end tank radiator and heater core production. Heating and cooling systems accounted for 12% ($360 million), the second most significant area, of Acustar's 1988 sales. The concentration of sales in this area may lead Chrysler to protect this segment through capital, engineering and design, and manufacturing human resource investment. Although Chrysler seems to be backing away from compressor production, Chrysler appears committed to heat transfer (radiator and condenser) production, investment, and innovation—particularly in the aluminum heat transfer component area.

The driving force behind this trend towards aluminum heat transfer components is lighter vehicle weight while maintaining heat transfer efficiency to assure passenger comfort. As with all component products, Chrysler component plants will feel pressure to improve productivity and quality to match outside suppliers (in this area, Blackstone and Modine as well as GM's Harrison Radiator Division and Ford's Climate Control Division are likely to aggressively seek outside contracts). To gain international aluminum technical expertise Chrysler entered a joint venture with Valeo of France. The trends noted above will likely lead to product technology changes. This will, in turn, lead to new product production and associated aluminum fabricating and manufacturing requirements. As with all new manufacturing investment, there is an associated risk of employment loss through automation, as well as pressure to consolidate and rationalize production based on final vehicle capacity needs and productivity improvements. These areas should be monitored. Overall there will be a need for training to achieve quality improvements through the use of control measures (SPC, QFD, and other methods).

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Automotive Product Technology Impact Study
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Brakes, Wheels, Tires Subsystem

Component	Current Practice/ Configuration	Driving Forces	Likely Changes
Front Brake Caliper Assembly	Cast iron caliper with friction brake pads and associated hydraulic and mechanical hardware; ABS also integrates wheel speed sensor.	• Performance • Fuel economy • Packaging • Quality (durability) • Safety performance and regulation	• Increased application with increased penetration of 4 wheel disc ABS. • Redesigns for lighter weight. • Increased durability of friction materials/lower maintenance.
Master Cylinder/ ABS controls	Metal housing with stamped steel lid and blow molded reservoir; ABS controls include electric pump, rotation sensors, logic control, and actuators.	• Performance • Safety • Competitive standards/ offerings • Cost reduction • Safety performance and regulation	• Continued integration of master cylinder and ABS controls. • Beginning integration of traction control systems. • Material substitution.
Rear Drums/ Rotor	Cast iron drums (some aluminum applications) with friction brake shoes and associated hydraulic and mechanical hardware; ABS also incorporates speed sensors.	• Performance • Packaging • Fuel economy • Cost reduction • Safety performance and regulation	• Increased use of composites. • Slight decreasing usage with increase of four wheel disc brake units. • Increased durability of friction materials/lower maintenance.
Wheels	Stamped steel and cast aluminum.	• Competitive standards/ offerings (styling) • Cost reduction • Fuel economy • Safety performance and regulation	• Increased aluminum casting application for weight reduction and styling reasons. • Application of composites. • Redesign to accommodate new tire technology.

Brakes, Wheels, Tires Subsystem

The most likely significant development over the next decade will be the complete application of anti-lock brake systems (ABS) across all passenger car and light truck programs. ABS systems incorporate electronic and electrical controls to modulate brake pressure in panic situations. These systems will be standard features, although a few base and entry level models may offer these only through option packages. The manufacturers are leading the application of this major safety feature, so regulation is unlikely unless a significant number of vehicle lines remain uncovered by the end of the decade. Currently, Chrysler offers ABS on its performance and mid-size and above passenger cars. Compact and most Jeep products are not covered. With this focus on ABS and four-wheel disc brake systems, employment associated with drum brake or non-ABS compatible components is likely to be at risk, except for service-related production, which will, of course, decline over time.

All new platforms will permit the offering of ABS. It is best to consider the packaging issues of disc brake calipers and rotors and sensors/actuators in the wheel area, the master cylinder controls in the engine compartment, and the associated electronic module and wiring and hydraulic lines throughout the rest of the vehicle. Chrysler's Acustar Huntsville Electronic Division provides electronic ABS control modules for a variety of its programs. It is likely that a significant amount of engineering and design activity will be directed to new systems as well as redesigning existing systems. These will provide increased circuit integration (to improve reliability and reduce the size and weight of the module package) and improve diagnostic capability. The integration of traction control into the ABS module will be particularly important for upscale and performance vehicles. Traction control may be viewed as ABS in reverse—sensors detect rapid wheel spin (rather than wheel lock-up) and apply the brake at that wheel (rather than disengage the brake). Traction control systems on vehicles equipped with ABS result in additional integrated circuit and software value rather than in additional manufactured components.

Chrysler depends upon joint activities with outside suppliers to develop the appropriate system. It is likely then that Chrysler will stay competitive in terms of packaging, weight reduction, and cost reduction because these suppliers source into every vehicle manufacturer. Chrysler benefits from shared R&D, capital investment, and other activities performed by these suppliers with cost spread across far more than just Chrysler's production contracts.

Chrysler's most significant manufacturing activity in this area appears to be brake master cylinders, front-wheel drive bearing supports, and knuckles. Each of these components is likely to be redesigned to accommodate ABS. These components are also likely to be outsourced because of the drive by "systems" or "modular" suppliers to propose complete systems engineering and sourcing. If Chrysler pursues "black box" sourcing—where the supplier provides design, engineering, and complete systems manufacturing responsibility based on specific vehicle performance criteria and engineering and marketing parameters—then jobs may leave Chrysler for these suppliers' plants. It is therefore critical that Chrysler invest in the capabilities of its brake-related plants. Precision casting will be essential for master cylinder production to keep this production in-house, and to forestall material substitutions that are beyond the capabilities of the metal-forming brake plants. Plastic has already made inroads in the reservoir and cap areas and there do not seem to be significant barriers to plastic usage in the master cylinder body as well. This may lead to component production rationalization.

All other components on this matrix are externally sourced. Therefore, the likely changes will impact Chrysler suppliers. As with other matrices, Chrysler design and engineering has the responsibility to keep pace with segment competitors to assure consumer value.