AIM '86

Fiscal Year 1986 Report of the Auto-in-Michigan Project

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16. Abstract

AIM '86 reports on the fiscal year 1986 findings of the Auto-In-Michigan Project, established by Michigan state government to explore likely developments in the automotive sector in Michigan in the 1986-92 period and to recommend public policies to address those developments. AIM '86 reports on continuing research on vehicle electronics, materials, stamping, engine manufacturing, and engineering services. In addition, it describes 1986 computer modeling work on major input sourcing and the increased use of foreign parts in U.S.-assembled cars.

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Executive Summary

The Auto-in-Michigan Project: 1986 Report

Introduction

Since January, 1985 a team of researchers, consultants, and industry analysts has been providing Michigan State government with detailed information and analysis on the state's major industry. In this brief executive summary, we describe the Project's fiscal year 1986 activities (see the *AIM'85* executive summary for more detail on FY 1985 work) and preview what lies ahead. As befits a now-mature effort such as AIM, many of our activities are open-ended, spanning arbitrary calendar and fiscal year boundaries.

FY'86 Research

Much of our 1986 work has built on three key findings made in our first year:

- A significant change in the relationship between technology and the appropriate sizing of production operations;
- Engineering plastics' growing viability as a replacement for steel in both vehicle skins and structural components; and
- Emerging changes in the locus of responsibility for design and manufacture of vehicles and their subsystems.

Based on the first of the three, we have undertaken a study of *engine manufacturing strategies*. This year's work on engines has focused on the spatial distribution of engine value-added and on the challenge posed by increased use of electronics in powertrain control.

On the first of these, among our tentative conclusions is that the current organization of engine-making -- large captive foundries serving highly-integrated engine plants set up to run engines in a module size of 1600 per day -- can no longer be assumed optimal. For Michigan, which makes engines for twice as many cars and light trucks as it assembles, the emergence of smaller, more flexible engine plants serving one (or at most a few) assembly plants promises major dislocations. Even if an alternative approach of fewer, much larger engine plants becomes the norm beyond the 1990s, the state's many captive foundries and engine parts plants face grave risks. At the same time, the "decontenting" of engine plants presents new opportunities to independent casters and parts specialists, if they have what it takes. In every scenario analyzed, sharply increased utilization of expensive flexible equipment will demand greatly improved and systematized management and hourly workforce practices. Recent and continuing work focuses on emerging casting and part-making designs and process approaches, and is aimed at identifying the requirements for competitive success in supplying 1990s engine programs. A brief introduction to the casting work appears at the end of the "Engine Manufacturing" section of this Report.

In the *electronics* area, AIM work has made two significant findings. First, because U.S. automakers have often used electronics to make up for their often less-than-modern basic engine designs, electronics could become *less* rather than more essential in the manufacturers' powertrain strategies if engines are redesigned, as many are expected to be in the decade ahead. Second, to the extent that engine electronics do continue to grow in importance, they will generally not gain at the expense of mechanical components, but instead represent additional value; the only obvious exceptions are electronic fuel injection replacing carburetion, and emissions electronics displacing some pumps and manifolding. There is some post-1992 potential for dislocation to mechanical linkage parts from electronic throttle ("drive by wire") and variable valve timing; electronics-intensive control strategies for automatic transmissions may also deal out certain mechanical control element suppliers. In any case, only suppliers that come forward with high-quality, low-cost contributions to powertrain design and control efforts will prosper.

Building on our materials research of 1985, AIM has peered several layers deeper into *the steel-plastics competition in major body panels*, and broadened the inquiry to include an assessment of the entire system of transforming steel into automotive stampings. The new work strongly suggests that properly tooled and managed steel press plants can compete successfully against plastic panel operations, and this has led us to revise somewhat our bold 1985 predictions of a major surge in plastic-bodied vehicles. However, we also see large, perhaps insurmountable, obstacles to successful futures for many of the large, captive regional stamping plants. Since Michigan hosts twelve such plants and, as with engines, is more involved there than in vehicle final assembly, those obstacles are a major concern. In a market context in which the number of Big Three traditional domestic car and light truck sales may soon decline significantly, major outsourcing of body panels would deal a body blow to many -- perhaps most -- of the captive regionals. While Michigan hosts some highly competent independent stampers, there is also the possibility that Japanese firms located in the U.S. will take over much of the business shed by the captives. Attention to the tooling -- both steel die and plastic mold -- sector is thus a priority, as is a major upgrading in how captive and independent press plants are operated.

The third 1985 major finding led us to focus on a little-studied aspect of the increased role for independent supplier firms in the chain of automotive value-added: the burgeoning *engineering service sector.* Michigan hosts hundreds of such design specialist firms, and these firms' Michigan operations do on the order of $450 million a year in business with the automakers, a figure that could rise to $600 million or more by the early 1990s. It is still far from decided how this sector will "fit" with the rest of the automotive design and manufacturing complex. Will it remain mainly an "annex" of the Big Three, doing "extra" work on particular projects, or actually replace major automaker design operations? Will its relation to the manufacturing firms be on the model of a construction company that coordinates the work of many small subcontractors, or more on the model of a law firm that does most of the work and subcontracts only a few specialized tasks? Our work suggests that it may well be to the traditional manufacturing suppliers that the Big Three turn for engineering, outsourcing design as well as manufacturing to the same place. If so, how will those suppliers interact with the engineering service sector? Finally, this sector may help anchor manufacturing work in Michigan, though this will be more true of part than of complete vehicle design work. CAD, a mainstay of the engineering service firms, could in principle loosen the historically close ties between major design and production acitivities, but our findings suggest that face-to-face contact remains a powerful force keeping design proximate to manufacturing.

Dissemination

Presentations:

In the past year, the AIM staff has taken the Project's findings on the road. Information gathered from the Project's survey work with local economic development agencies (LEDAs) around the state[1] has produced an *establishment database* with completed records on 1400 Michigan automotive facilities, based on a mail survey of over 10,000 establishments.[2] Survey results have been analyzed and presented at seminars organized by LEDAs in Detroit, Macomb County, Washtenaw County, Jackson County, Grand Rapids, Bay City/Saginaw, and Flint. Attendance has included hundreds of representatives from local supplier and auto manufacturer establishments, public and private sector economic development groups, and educational institutions. An expanded slide show[3] has been developed and presented, often in conjunction with the Technology Deployment Service (TDS) slide show. For many firms, TDS offers a program that fits well with the risks and opportunities identified by AIM research.

Vehicle Program Siting

The project has continued to chart the health of current, and the prospects for new, vehicle programs in Michigan assembly plants. We continue to be gravely concerned about the same four high-risk plants we discussed in the FY'85 AIM Report: GM's Clark/Fleetwood and Pontiac #8, and Ford's Wayne and Dearborn assembly plants. The decision to defer indefinitely the GM80 program may doom the Pontiac plant, and we know of no firm post-1989 plans for Clark/Fleetwood or Dearborn. We continue to fear that overcapacity in small cars places the Wayne plant at risk in the 1989-92 period

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[1]See the "Resources" section of this Report for a list of the LEDAs with which the project worked. There were sixteen during the FY'85 survey, and six more were added in FY'86.

[2]The AIM database has been used extensively over the past year by a number of groups. The Project has not sought to publicize the existence of the information, so as not to overwhelm a small staff with requests that could prevent us from completing other activities. Even with this lack of publicity, State and local economic development personnel have frequently utilized the information. Examples include requests from account executives in Commerce's Manufacturing Services Bureau. Since the database has extremely detailed product detail, it has been useful for prospects looking to identify joint ventures or local suppliers. The supply linkages it shows were useful for a local official interested in the effects of a strike by a major auto manufacturer on firms in his area. Information on technology usage and interest was used by the Technology Deployment Service in developing a list of potential clients for its pilot phase; many of these firms later became clients of TDS. A training program currently being developed by a community college used the technology information in evaluating the size and depth of the potential market for its services.

[3]The slide show's final section includes aggregate results from the AIM survey of Michigan auto supplier establishments. Data are presented at two levels, statewide and for each local area. The information presented includes distributions by employment size, line of business, and unionization; the percentage of total sales related to auto, the number of facilities that supply our respondents and the extent to which these are Michigan-based, and a summary of current and future usage of a number of advanced manufacturing technologies.

as well. The Project has attempted "risk analyses" of the state's seventeen car and light truck assembly plants, with updates appearing in each issue of the AIM Newsletter, copies of which are provided in this Report. The most recent ratings are summarized below:

1986-1992

Co.	Plant	Current (1986) Program(s)	Risk factor: Age of Current Program – Future Plans	Risk factor: Attributes of Plant	Risk factor: Perceived Labor Climate	Risk factor: Imports or Out-sourcing	Plant Risk Score
GM	Clark/Fleetwood	B,D	8	8	6	0	22
	Pontiac 1	P	3	2	2	7	14
	Pontiac 8	G	9	6	3	2	20
	Pontiac 5	S10	5	2	4	3	14
	Willow Run	H	0	3	5	2	10
	Buick City	H	0	2	3	2	7
	Lansing	N (2 plants)	2	4	4	6	16
	Orion	C	3	2	7	2	14
	Flint Truck	C/K,K	7-2	4	8	0	17
	Poletown	E/K	0	0	3	2	5
Ford	Wixom	LS, Panther	7-3	3	4	0	11
	Wayne (Truck)	Bronco, F	7-4	3	4	0	11
	Wayne (Car)	Erika	6	2	2	9	18
	Dearborn	Fox	8	5	3	5	21
Chrysler	Jefferson	K,E,CV	8-6	5	2	4	13
	Sterling	H,P	2	2	4	5	13
	Warren	D/W,N	0	1	4	3	8

(A "Plant Risk Score" of 20 or higher indicates grave danger; 15-19 indicate significant risk.)

On-going efforts to assess the risks and opportunities facing Michigan assembly programs were expanded in FY'86 to include a business and employment forecast for all Big Three and major independent supplier establishments in the State. These plant-level forecasts have been useful to the Commerce Department's Auto Policy Group in planning the FY'87 Renew program (see below).

Sourcing Database:

In the FY'85 AIM Report, information was presented on the sourcing of the major components (stampings, engines and their block and head castings, and transmissions and their major castings) of Michigan-assembled vehicles. Information obtained from consultants and the trade press in FY'86 has extended the coverage to include (i) the sources of more components (water and oil pumps, manifolds, exhaust and fuel management system parts, wheels, brakes, steering and suspension parts, etc.) of Michigan-assembled cars and light trucks, and (ii) sources for the stampings, engines, transmissions, and axles that go into virtually all light vehicles built anywhere in North America. This was felt to be necessary since virtually all domestic vehicle programs utilize some components from Michigan facilities.

The volume of this data, as well as the requirements for flexible reporting, led AIM to organize the information into a computer database run in *dBaseIII+*. This format allows for easy updating of information, as well as display in a format easily understood. The program is menu-driven, both for input and output. Information is available on particular plants, vehicle programs, engines, transmissions, and various parts. The following is an (expurgated) excerpt from the output of a basic record on General Motors' D-body car program.

PROGRAM

VEHICLE PROGRAM NAME	D
COMPANY	GM
DIVISION	BOC
LAUNCH YEAR	1977
OVERHAUL YEAR	See notes field
END YEAR	1990
DRIVE	RWD
CAPACITY	

PLANT(S) ASSEMBLING VEHICLE

PLANT NAME	FLEETWOOD/CLARK STREET
DUNS NUMBER	5356704
COMPANY	GM
DIVISION	BOC
PERCENT OF VEHICLES	
PERCENT OF PLANT OUTPUT	12
NOTES	50 JPH 2 SHIFTS

ENGINES USED	%	NOTES
CHEV 4.3 V6	15	
OLDS 5.0 V8 307	85	IN BOTH CAD & OLDS

TRANSMISSIONS USED	%	NOTES
THM 200 R4		
THM 700 R4		

(Additional reports can show the location of assembly for the engines and transmission listed above, as well as the facilities involved in production of major engine and transmission parts.)

VEHICLE PART PLANTS

PART NAME	UNDERBODY
PLANT NAME	CPC FISHER BODY GR METAL
DUNS NUMBER	6020408
COMPANY	GM
DIVISION	CPC
MATERIAL	STEEL
PERCENT	100

PART NAME	CHASSIS
PLANT NAME	FLEETWOOD/CLARK STREET
DUNS NUMBER	5356704
COMPANY	GM
DIVISION	BOC
MATERIAL	STEEL
PERCENT	100

PART NAME	DRIVE AXLE 8.5 INCH
PLANT NAME	DETROIT GEAR & AXLE
DUNS NUMBER	86744802
COMPANY	GM
DIVISION	SAGINAW
MATERIAL	IRON/STEEL
PERCENT	100

PART NAME	FRAME
PLANT NAME	A O SMITH
DUNS NUMBER	77703
COMPANY	A O SMITH
DIVISION	
MATERIAL	STEEL
PERCENT	100

Electronic Clipping Service on **Confer***:*

In the last year, AIM has continued to monitor the trade and popular press for current information concerning investments, equipment orders, product plans, sourcing decisions, technology utilization, labor agreements, and other topics that pertain to Michigan's auto-related establishments. Over 1100 items are now available, with an index file to assist users in quickly locating articles of interest. These files have been used for a variety of purposes by State and local economic development officials. Examples include trends in the robotic industry, sourcing and siting of current vehicle programs, new investments in particular localities, and background information on particular companies in preparation for site visits. The clipping service operates on the Confer electronic conferencing system, which also connects all AIM Project participants on a 24-hour-a-day basis. Since January, 1985 the Project's 17 participants have logged 71,000 minutes of Confer use to enter 235 permanent items and send 19,500 messages.

Modeling AIM Predictions

The AIM Project is currently working with the Regional Economic Models, Inc. (REMI) research team at the University of Michigan on a number of projects developed from AIM research efforts. Three major areas are under investigation:

The Value of Content

In recent years, major Japanese automakers have committed to build assembly facilities in North America. Mazda has committed to such a facility in Flat Rock; construction is well underway, with production expected by late 1987. While the economic impact of the assembly facilities is certainly important, automotive assembly facilities are highly valued due to their unusually large indirect (supplier) employment. Since the "transplants" source much of their componentry and nearly all their production equipment from Japan, the impact of transplant assembly plants is reduced. The increased outsourcing that may occur from Big Three assembly facilities in the near future makes this issue even more critical for the state.

Challenges to Body Panel Stamping Plants

The AIM Project has predicted movement from steel to plastics in major body panels. For Michigan, this will have a significant impact, both in terms of reduced demand for output from many captive stamping plants, and increased demand from plastic fabrication facilities, many of these independent of the major automakers. The REMI team is investigating: (i) the impact on stamping of the declining output of domestic manufacturers due to competition from transplants and imports, (ii) the shift from steel to some or all plastic panels in some vehicle programs, and (iii) the tendency to shift production of steel panels from regional to assembly-contiguous facilities. The extent to which Michigan's assembly share and/or local sourcing of plastic panels would have to be increased to offset the economic loss due to declining stamping output is also being examined.

Potential Rouge Cutbacks

The Rouge complex includes frame, assembly, steel-making, tool and die, stamping, glass, and engine facilities. Particularly if the assembly facility fails to land a successor program to the Mustang, many facilities in the complex may be at risk. Based on detailed information on the links between the various facilities, REMI is running simulations of the economic impact of various levels and orders of closure.

Renew and AIRS

The Department of Commerce, through the Auto Policy Group and Auto Working Group, has recently launched the "Renew" program. In this program, Commerce Department account executives will visit every OEM production facility and selected major supplier plants in the state to establish direct contact with plant management and local union leadership.

This program will expand on the AIM Project's already extensive establishment-specific database of auto suppliers, with an emphasis on the largest facilities. It will provide information not only on these establishments, but also on smaller facilities that rely upon these firms for business.

In order to support Renew, an Auto Industry Research Section (AIRS) has been formed as part of Commerce's Innovation and Technology Services bureau. AIRS will gather and analyze information obtained by Renew and AIM so that AIM findings are widely available within State government, and to ensure that policy-makers have the data necessary to pursue an informed strategy toward the state's most important industry.

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September - 1986

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Economic Development
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Dearborn

Automotive Industry
Engineering Outsourcing:
Implications for Michigan

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EXECUTIVE SUMMARY

The Engineering Service (ES) industry today comprises some unknown number of firms and practitioners, probably constituting more than 1,000 different "businesses." The largest two dozen firms may well account for over half of the total employment of Michigan's ES industry, which is estimated to number 15,000 to 20,000 jobs. This industry has developed from the old "contract engineering" shops that typically provided a pool of temporary technical manpower for the manufacturers. More recently, some of these firms have taken on major design responsibility for vehicle bodies and major engineering responsibility for vehicle components. These firms represent an alternative source for engineering services to the traditional part and component suppliers, and an additional source of engineering services for the manufacturers that is not directly tied to the manufacturing of the product.

AIM efforts in the manufacturer-supplier area focused on these ES suppliers for the following reasons:

- The ES industry is centered in Michigan, currently providing a substantial number of jobs;

- The Big Three have all indicated that they plan to rely more on suppliers' technical capabilities and engineering resources in the future, and hence the ES industry may experience significant growth;

- The ES industry may provide leverage for the State in the retention of manufacturing jobs at both the manufacturer and supplier levels of the industry; and

- The ES industry may provide the state's suppliers an advantage in maintaining or securing the higher value-added status of first, rather than lower, tier.

Our efforts included interviews with the Big Three manufacturers, seven ES suppliers, and 15 suppliers of parts and components. They covered the market for and patterns of engineering outsourcing, supplier relations, and the development of the ES sector and its relationship to manufacturing activities. The ES respondents included four presidents, two vice presidents, and two managers. The traditional supplier respondents included 12 vice presidents; the balance were directors or managers. The Big Three provided multiple respondents, most at a director level, drawn from engineering areas at two of the companies, and from purchasing at the third.

Big Three 1985 purchases of ES services:

- Totaled $500 - $600 million;

- Were at least 75% domestic; and

- Were heavily concentrated in Michigan companies (86%), which

- Performed almost all (95%+) of their work here.

The market is expected to grow by about 40% by 1992, with some erosion (to 70%) of the domestic share, but with Michigan maintaining both its shares of domestic effort. Traditional suppliers also purchase ES services, but at a sharply lower level, totaling under $100 million a year.

As in other automotive areas, the critical issue for Michigan is to protect its current level of activities; realistically, there is not much chance of increasing that level substantially, but there is some risk that the level may fall.

The development of the ES sector, and the State's retention of its activity, is likely to be shaped critically by other emerging trends, including:

- The auto industry is placing increased emphasis upon the *simultaneous engineering* of the product and the process that will be used to manufacture it, and the way the manufacturers will balance this with the pressure to outsource both forms of engineering, often to different sources;

- The manufacturers prefer to outsource engineering work to the supplier that will manufacture the part or component, and that makes their location, success, and degree of reliance upon ES firms important to the location of those ES firms;

- Engineering and technical capability are likely to be the primary selection factors for first-tier suppliers, while manufacturing excellence may be the critical survival determinant for lower-tier suppliers, and the role of the ES supplier in supporting these two paths to survival of traditional suppliers is as yet unclear;

- Whether the ES industry develops into an industry of general contractors and subcontractors (like the construction industry) or an industry dominated by full-service suppliers (like the corporate law firm) is currently unclear. The second model may mean more activity in Michigan, but of a kind that may be harder to hold;

- The manufacturers are sending out larger programs, and larger programs will be less constrained by the proximity useful for intense supervision and monitoring when the part being engineered must fit with surrounding parts developed by other sources; and

- The rapid introduction of electronic communications technology *may* loosen the holding power of the Detroit area as the center of design and engineering, by shrinking the coordination costs and problems of remote work.

The courses of action open to the State are limited. There is no question that this industry finds the calculation base of the Single Business Tax onerous. The ES sector could benefit from programs at community colleges and four-year institutions to provide the personnel they require and the continued training that will ensure the development and maintenance of design skills. They do need designers, and the skills required of their employees have changed enormously with the advent of Computer-Assisted-Design (CAD). It may also be the case that the State could provide some "consortial" centralized resources for ES firms to draw upon, particularly in the area of computer hardware and time-sharing systems.

I. INTRODUCTION

The 1985 AIM Report identified a number of changes and developments in the relationship between the automotive manufacturers and their traditional suppliers of raw materials, parts, and components. These included:

- The manufacturers' widened sourcing options, and their related reconsideration of what goods and services to purchase from outside suppliers rather than make or perform internally;

- The manufacturers' likely increase in modular sourcing; and

- The manufacturers' increased reliance on suppliers for technical and engineering contributions.

International competition has forced the domestic industry to heighten its attention to issues of quality and cost. These two concerns have become the basic drivers influencing myriad decisions throughout the industry. Both quality and cost play a role in the manufacturers' increasing reliance on nondomestic sources, and their strategy of decreased vertical integration through increased outside sourcing. Quality and cost considerations also influence the patterns of how they source from suppliers. The manufacturers would like to reduce their number of direct suppliers and the associated transaction costs, and this has resulted in an emphasis on modular sourcing rather than the sourcing of constituent discrete parts for assembly by the OEM. Finally, quality and cost have influenced the OEMs' expectations about what the supplier should be providing. In particular, the manufacturers would like to rely on their suppliers for a higher proportion of the engineering work than has historically been the case. This would eliminate duplicate effort, allow the work itself to be performed at a possibly lower cost, and provide the benefits of accomplishing design and manufacture within the same company.

All of these changes have implications for how the engineering for a vehicle and its components will be accomplished in the future. There is little doubt that the OEMs' engineering staffs will shrink, partly due to improved efficiency through both organizational and technological changes, and partly due to the transfer of required engineering activities to outside suppliers. Outside suppliers will have to shoulder the responsibility for much of the engineering work currently performed by the manufacturer, and their capacity to do so will likely be an important determinant of their future success.

Exactly how the engineering for vehicles is accomplished in the future has implications for the prospects of the automotive industry in Michigan. The 1985 AIM Report identified a hierarchy of importance to the State of holding different types of automotive manufacturing facilities. In order of importance, they are

- the vehicle assembly plants;
- modular suppliers; and
- suppliers of the discrete parts and components that are combined into modules.

This chain reflects the role of each type of facility in wealth-creation within the State, and also its potential holding power for facilities lower in the chain. For example, keeping an assembly plant increases the likelihood of retaining first-tier suppliers, and this combination sharply increases the likelihood that smaller Michigan supplier companies will survive because of their proximity to consumers of their output higher in the chain.

Modular sourcing will pressure the U.S. industry to become more "tier-like" in its structure, with fewer suppliers selling directly to the manufacturers; these "first-tier" suppliers will become the major customers for the surviving "second-tier" suppliers. First-tier, modular suppliers, therefore, are critical to the Michigan automotive endowment in their own right, and also because of the role they will play in retaining the activity of smaller, less technically strong suppliers. Engineering and technical capability are quite likely to be primary selection factors for first-tier suppliers, while manufacturing excellence may be the critical survival determinant for lower tier suppliers.

The AIM Report identifies some of the likely candidates for first-tier roles as having both opportunity and risk in the transition to the new structure. The opportunity is to increase the proportion of their high value-added activity as a first-tier supplier; the risk is to fall back into a second-tier role. Of course, the higher the proportion of these Michigan supplier that succeed in becoming first-tier modular suppliers, the greater the benefits, both direct and indirect, for the State.

The manufacturers have another option besides the transfer of engineering to production goods suppliers. There is a burgeoning sector of the automotive supplier industry made up of engineering service (ES) firms. These are specialty engineering and design houses that until quite recently primarily provided the manufacturers with engineering and technical personnel to meet peak demands or to staff projects of fixed and limited duration. They provided a pool of temporary technical manpower for the manufacturers. More recently, some of these firms have taken on major design responsibility for vehicle bodies and major engineering responsibility for vehicle components. These firms represent an alternative source for engineering services to the traditional supplier, and an additional source for engineering services not directly tied to a product. At the same time, they can perhaps serve as a resource for traditional suppliers that must upgrade their technical contribution to become first-tier.

For these reasons, the focus of AIM II efforts in the supplier area has been on the emerging sector of Engineering Service suppliers. Our inquiry is structured around issues likely to impact the patterns of sourcing automotive engineering, and rests on interviews with the manufacturers, engineering service suppliers, and traditional suppliers of parts and components. This strategy permits the triangulation of the views of the three important actors in the evolving changes in automotive engineering, and that should ensure the identification of the major drivers and parameters of these developments.

II. BACKGROUND

Michigan currently has a rich endowment of engineering service suppliers, probably encompassing over 1,000 separate firms, partnerships, and sole practitioners that provide 15,000-20,000 jobs. But, as in the case of potential first-tier modular supplier, this sector of the Michigan automotive supplier industry faces a time of opportunity and risk. The opportunity is enormous: as the OEMs reconsider how the engineering for a vehicle will be performed, potentially massive amounts of work, and work with more technical (and therefore value-added) content may become available to these suppliers. Moreover, traditional suppliers that lack the full technical capacities to become first-tier modular suppliers may seek assistance from ES suppliers to offset their weaknesses. The specific risk for these ES companies is relatively small, and is primarily represented by the possibility that traditional suppliers might service the expanded needs of the OEMs.

The ES endowment of Michigan represents a potential opportunity for Michigan in a number of ways. The expansion of this sector holds promise of the development of well-paid, desirable jobs that are important to offset the job losses likely from the reduction in the engineering activities of the OEMs. The strong presence of the ES sector may represent an asset for traditional suppliers in the State. Finally, the maintenance of Michigan as the center for this kind of support service to the manufacturers might provide some leverage for the retention of the manufacturing jobs the industry provides at both the manufacturer and supplier levels. This sector of the supplier industry, then, is important in its own right and perhaps for the indirect benefits it might provide in other wealth and job creating segments of the industry.

For the State, however, there are risks in the ES sector that are far from small. Michigan currently dominates this sector and is clearly the market leader, but there are serious questions as to whether this position can be maintained. As with all suppliers, the likely shrinkage of Big Three production share represents potential business lost to other geographical areas, as domestic vehicle programs, component work, and facility construction and modernization are reduced. The rapid introduction of electronic communications technology may loosen the holding power of the Detroit area as the center of design and engineering, as the coordination costs and problems of remote work shrink. It is unclear whether Michigan has the technical worker pool to support serious expansion of the ES industry, should that be required. As in other automotive areas, the critical issue for Michigan is to protect its current level of activities; realistically, there is not much chance of increasing that level substantially, but there is real risk that the level may fall. But maintaining the current leadership in engineering services may provide the State powerful leverage in defending its current activity levels in the traditional part and component supplier sector of the automotive economy.

III. INTERVIEWS

The ES interviews were constructed to take approximately one hour, and supplemental information appropriate to written responses was gathered from the ES suppliers through a short questionnaire. The interview protocols and the questionnaire are appended to this report. The interviews and written questionnaire bridge a number of topic areas, and these will form the subsequent divisions of this report. They are:

- The market for engineering services;
- Patterns of engineering outsourcing;
- Engineering and manufacturing;
- Drivers for the increased OEM reliance on ES suppliers;
- Barriers to realizing the benefits of Computer-Aided Design (CAD);
- Changes in the OEMs' selection criteria for ES suppliers; and
- The advantages and disadvantages of Michigan location.

Each interview was conducted at the respondent's office, and lasted from 45 minutes to an hour and a quarter. This variation largely reflected the applicability of our questions to the business of the respondent firm. The more complex their automotive business, the longer the interview. Suppliers with multiple customers and projects often answered in great detail to avoid oversimplifying or biasing their comments. By and large, respondents appeared eager to cooperate and quite open in their comments.

The interviews with the manufacturers covered the market for and patterns of engineering outsourcing, supplier relations, and the development of the ES sector and its relationship to manufacturing activities.

The interviews with traditional suppliers of raw materials, parts, and components (RMPC) covered a number of topics relevant to that industry. The material included in this report is drawn from responses to six questions that focused on the general topic of engineering outsourcing by the manufacturers, with particular emphasis on the likely role of the ES sector in this regard. This portion of the interview for traditional suppliers is also included in the appendix.

IV. RESPONDENTS

Companies

Seven ES firms were identified through press coverage and nomination by knowledgeable industry observers. Because of this procedure, they are among the larger and more substantial service companies. They are thus unlikely to be typical of the many smaller shops with fewer than ten employees that are an important component of this industry. This limitation is acceptable, however, because the more critical developments in this industry that are of concern to the State in all likelihood will involve the capabilities and prospects of these larger engineering service companies.

These seven ES firms are larger than the typical firm size for the industry, and cover roughly twenty percent of the probable workforce in the ES industry. They perform about 96% of their service activity within Michigan, and primarily serve the product rather than the process engineering needs of the OEMs. Their work is almost exclusively automotive (roughly 90%), and for the most part they see only moderate diversification away from automotive work by 1992. General Motors accounts for just over 50% of their business, while Chrysler at 28%, Ford at 16%, and AMC and VWOA at 5% make up the balance.

Each of the Big Three manufacturers agreed to be interviewed for this study.

The fifteen traditional suppliers interviewed are technically strong, good quality automotive suppliers, spanning a broad range of parts and components. Seven of them are headquartered in Michigan.[1]

Individuals

This type of inquiry faces an immediate problem, that of identifying an individual that can respond for a company. That requires someone highly enough placed to have an overview of the company's activities, but not so high as to have lost contact with the details of those activities. For the manufacturers, and some traditional suppliers, the problem is exacerbated by the sheer size and complexity of the company: it is impossible

[1]For a more detailed description of this sample, and a broader report of the interviews, see Michael S. Flynn and Robert E. Cole, Automotive Suppliers: Customer Relationships, Technology, and Competition, Industrial Technology Institute, June, 1986.

to select one individual that can appropriately respond across all the material contained in an interview such as this.

The ES respondents included four presidents, two vice presidents, and two managers. The traditional supplier respondents included 12 vice presidents; the balance were directors or managers. The Big Three provided multiple individuals, most at a director level. They were drawn from engineering areas and purchasing.

V. KEY FINDINGS

The ES sector is in itself an important component of the State's automotive endowment. It presents the opportunity to cover the losses likely at the manufacturers as they reduce their engineering activities.

The ES sector provides two indirect benefits to the State in holding other automotive activities. First, it likely has some impact on holding manufacturing jobs, as the industry struggles with the issue of integration. However, this impact is at the margin, and not a primary consideration in the decision to locate a manufacturing facility. Second, it should play a role in strengthening the Michigan supplier base for the predicted shakeout. The strong ES sector may provide the supplemental capabilities that assist our traditional part and component suppliers in their attempts to become or remain first-tier, and may also assist those that are or become second-tier in surviving.

The development of the ES sector is likely to be shaped critically by two other emerging trends in the industry. The first of these is the increased emphasis upon *simultaneous engineering* in the domestic automotive industry. Simultaneous engineering involves the coordinated, integrated development of the design of the product and the design for the process that will be used in its manufacture. It promises a wide range of cost reductions, spanning material savings and improvements in manufacturing productivity. Simultaneous engineering should reduce manufacturing labor content costs, and thus it holds some promise for the retention of manufacturing jobs in Michigan. As the ES sector is currently structured, most firms specialize in either product or process design, so that more than one firm would be involved on a typical project. That may exacerbate the very problems of integration that the manufacturers would like to overcome. To be sure, some ES firms do possess capability in both design areas, and there are reports that other ES firms are establishing cooperative arrangements to address this issue. How well the ES sector is able to meet the demands for simultaneous engineering may be a critical determinant of its growth.

The second development that will impact the development of the ES sector is the distinct, though related, emphasis upon the technical contribution of the traditional parts and component supplier. The manufacturers see these traditional suppliers as logical sources of engineering assistance because of their depth of expertise in the product area, and because such assistance can readily provide the benefits of simultaneous engineering plus the benefits of integrating both types of engineering with manufacturing. For these reasons, the reliance of the manufacturer upon ES may depend on the performance of traditional suppliers. ES may be a second choice for engineering outsourcing. If traditional suppliers perform this service well, the ES sector may change not so much in the type and level of service it provides as in the exact customer base it serves.

The State faces a choice as to whether it wishes to encourage the development of ES as a "replacement industry" or as an industry that complements the current manufacturer and traditional supplier base. The latter course may provide more total leverage for maintaining the current activity levels of the State's automotive sector, since it holds promise of some impact on activity beyond the engineering area.

The size of the programs that the manufacturers send out has two implications for the State. First, larger programs will be less constrained by proximity. Both the volume and type of work that is involved in larger programs prohibits the manufacturers from the close supervision and constant checking of progress that is possible when a specific activity such as drafting, or a limited program, such as an alternator mounting bracket, is outsourced. The manufacturers will have to transfer more of these responsibilities to the ES firm, or simply see the cost advantage of outsourcing disappear as the costs of coordination rise. The current importance of proximity is to provide convenience for the manufacturer and for the large number of its personnel currently performing these functions. The importance of proximity will lessen as smaller and smaller numbers of the manufacturer's personnel are required for supervision and coordination tasks. For Michigan, that raises the risk of losing ES work, especially in the higher value-added portion of the industry, where the larger programs will concentrate.

Second, these larger programs are likely to undercut the current cost advantage of the ES firms over the in-house engineering resources of the manufacturers. This is because the ES firms will incur more costs as they accept the responsibilities currently housed in the manufacturers of managing and coordinating the programs. Their overhead will grow. That may mean that there will be less frequent outsourcing of these larger programs than is currently expected. Since most manufacturer engineering activity is located in Michigan we may, therefore, lose a smaller, but still critical, portion of such activity to non-Michigan ES firms.

The courses of action open to the State are limited. There is no question that this industry finds the calculation base of the Single Business Tax onerous. The ES sector could benefit from educational programs at the community colleges and four-year institutions that are designed to provide the personnel they require and to provide the continued training that will ensure the development and maintenance of required skills. They do need designers, and the skills required of their employees have changed enormously with the advent of Computer-Assisted-Design (CAD). It may also be the case that the State could provide some centralized resources for these firms to draw upon, most probably in the area of computer hardware and time-sharing systems.

VI. OVERALL THEMES

Interviews take on many of the characteristics of a casual social situation and may become what one expert has called "conversations at random." The reason for this is clear -- the structure of the interview reflects the way that the drafter thinks about issues and how they are related, but the actual interview reflects the respondent's way of thinking about those issues. Thus there are important themes that emerged in the interviews that are scattered across different questions, depending on when the respondent chose to make the point. This kind of material is likely to be lost in a question by question review of the interviews because it forms a small portion of the response material for any given question. Consequently, we here present a brief overview of these themes.

The ES industry is a very fragmented one, and is currently undergoing substantial change. The responses of the ES interviewees reveal sharply divergent views, and even ways of framing the issues. This is in clear contrast to traditional suppliers' responses to similar topics. The traditional supplier is aware of the "conventional wisdom" of the industry, and makes it clear where he agrees or disagrees; the traditional supplier also is aware of general conditions in the industry, and where his company differs because of product, customer base, or other specific factors, and is careful to point this out. The ES suppliers, in contrast, often appear to have no shared frame of reference, no conventional wisdom or standard experience to counterpose to their own views. This lack of a coherent viewpoint is not surprising, and suggests an "industry" that is only beginning to emerge as a recognized player in its own right.

The Michigan ES industry, as noted above, comprises more than 1,000 businesses, mainly small firms, partnerships, and solo practitioners. Many of these smaller firms experience frequent reorganization, high turnover, and sometimes represent "shifting coalitions" of a few key people doing business under a variety of arrangements. Retirees from the manufacturers and their RMPC suppliers represent a significant source of personnel, especially for the smaller operations. Many observers think it is quite likely that the industry will concentrate rapidly over the next few years, finally shedding its "temporary job shop" image.

There are a number of fundamental uncertainties facing this industry over the next decade. There is little question that there are important changes in the level and pattern of work that the automotive manufacturers are securing from ES suppliers. More work is going out, and that work is more complex than it has been in the past. But exactly how these levels and patterns are changing, and what future evolution is likely is simply unclear. The fragmented views presented by these suppliers suggest they know there is a broad thrust of the manufacturers requiring them to perform a broader scope of activities than has been traditional, but have no clear sense of exactly how that scope is broadening. It is not clear, for example, whether that broadened scope will be accomplished through the enlarged activity of a particular ES firm, or by the specialization of existing firms, with broadened demands met at the level of the industry.

It is clear that the development of the ES industry will depend to some extent on decisions and issues that involve tangentially, if at all, the issue of engineering outsourcing. One manufacturer, for example, notes that internal pressures for integrating product and process engineering are somewhat in conflict with other pressures to reduce engineering headcount. Another observes that they are faced simultaneously with two goals that appear to be in direct conflict: reduce engineering outsourcing *and* reduce internal headcount. So, too, how satisfactorily traditional part and component suppliers provide engineering and technical services may be critical in determining the level of future outsourcing, and what portion of it is directed to the ES firms. It is also possible that ES will fragment into two different industries to serve the different requirements of the manufacturers and two tiers of suppliers. One industry might look very much like the contract service industry of the past, while the more "full-service" model develops in parallel.

There is a sense throughout these materials that the manufacturers' cost for both product and process engineering is the real driver behind these changes. If that is the case, then there are likely to be some consequences for how the ES industry develops. Cost pressures are likely to shape the industry along the lines of many specialized firms competing for limited pieces of the action, rather than permit the concentration of the industry into fewer, more broadly capable players, because these firms would face the same cost pressures that the manufacturers currently experience: coordination costs, costs of idle capacity, pressure on compensation costs, etc.

VII. MARKET SIZE

The current and expected size of the market is an important parameter in assessing the likely direction and shape of an industry's development. We are particularly interested in the likely evolution of the sourcing of engineering independent of production, outsourced engineering that is *not* embodied in a component or part purchased from the actual supplier. We asked both manufacturers and engineering service firms for information that would provide us some idea of how large a market exists for such services, and how much is likely to exist by 1992.

The ES suppliers estimate the 1985 market for the Big Three purchases of ES services at just under $700 million, ranging from $500 million to $1 billion. This market is currently seen as both heavily domestic (75%+), very concentrated in Michigan companies (86%), and with almost all of the work being performed here (95%+). The market is expected to grow by about 40% by 1992, with some erosion of the domestic share (to 70%), but with Michigan maintaining both its sales and activity shares of that domestic effort. One ES supplier estimated that traditional suppliers purchased an additional $50 million worth of ES services in 1985, but the rest were unable to put a dollar value on that market for their services. Most of the ES suppliers do expect some growth in that segment, and those that placed a number on the growth expect about a 50% increase.

The estimates the manufacturers provide for their own activity in 1985 suggest a market of just over $500 million. However, two of the manufacturers were quite careful to point out the problems they encounter in arriving at their estimates, so totaling these estimates, and adding amounts for other automotive companies does not necessarily provide an accurate accounting of the true market. The manufacturers outsource engineering at a number of points in the process and from a number of locations in the corporation, so it is difficult, even impossible, to come up with an exact account. In all likelihood, however, that market is indeed in excess of $500 million, and probably in the neighborhood of $600 million.

If anything, the manufacturers expect to see even more growth in ES by 1992, two expecting that growth to exceed 70%, and one estimating it at about 30%. Traditional suppliers indicate low usage of ES; this is consistent with the relatively small share of the total purchases that they currently make. Traditional suppliers' comments suggest that they do not see substantial growth in their reliance on ES. However, the suppliers interviewed are technically strong, and it may be that technically weaker suppliers *will* increase their reliance on ES.

We asked the ES suppliers whether the levels of engineering outsourcing differed among the Big Three, and if these levels have changed much in the past three years. All the ES suppliers report that the level of engineering outsourcing has increased over the past three years, but there is disagreement about how those levels differ among the Big Three. Two feel that Chrysler outsources the most, one ranks it second, and four report that it outsources the least. One sees Ford as the OEM with the highest level of outsourcing, while five rank it second, and one third. Four see GM as outsourcing the most, one as second, and two as the least. While we hoped to develop information about the proportion of their engineering each of the Big Three outsources, these rankings reflect more their relative sizes.

The interviews with the RMPC suppliers may shed some light on this pattern. None of these suppliers challenged the statement that the OEMs are outsourcing more, and nine of them provided comments that could be ranked to indicate how rapidly the Big Three are moving to outsource engineering. In the view of these RMPC suppliers, GM is moving more rapidly than Ford or Chrysler, and Ford just a shade faster than

Chrysler. But the more striking aspect of these rankings, as with those by the ES suppliers, is their variability. How rapidly a supplier thinks one of the Big Three is moving appears to be highly dependent on its product area, its levels of business at each of the Big Three, and the units of the OEMs' it supplies.

The manufacturers report that the dollar value of outsourcing of engineering has increased substantially over the past three years, one indicating a rate of about 10% per year.

VIII. PATTERNS OF ENGINEERING OUTSOURCING

A number of questions in the interview directly concern patterns of engineering outsourcing -- what and how the OEMs choose to source to an ES firm. We asked about changes in such patterns, whether the decision to outsource the engineering is related to a number of factors, the general nature of the relationship between the ES and the OEM, and what changes might occur by 1992.

Engineering Outsourcing

For the past few decades, the manufacturers have primarily relied on the contract engineering sector for two types of product engineering service. The first was to supply people to work at the manufacturer's location under direct supervision of the manufacturer's personnel. This form constituted a temporary employee service that one traditional supplier referred to as "rent-a-pencil." The second form was to work on projects for the OEM, but at the contract location. These projects were typically quite limited in scope and reflected immediate pressures upon the OEMs' own engineering staffs. Some, but very little, engineering was outsourced on a broader basis.[2]

ES suppliers believe that this pattern has changed. *The manufacturers are now sending out product engineering assignments for vehicles, components, and parts that were rarely outsourced just a decade ago.* Most notably, design houses have been contracted for entire vehicles. The manufacturers are also sending out work in packages or modules that used to be separately contracted, sometimes to different ES firms.

[2] It appears that broader process engineering projects have been placed at ES firms in the past.

Instrument panels are being outsourced as a package, for example, rather than discrete sourcing of its constituent elements. The manufacturers are also contracting out work on the chassis, transmission, and engine -- areas that have been quite restricted to in-house engineering for the past twenty-five years.

We also asked the ES suppliers whether the patterns of engineering outsourcing differed among the Big Three. Two suppliers felt that there is not much difference among the OEMs, but the remaining five made some interesting observations. Ford is viewed as sending out more sophisticated assemblies, more total programs, and stressing earlier supplier involvement, but also as outsourcing mainly body work. Chrysler is seen as sending out more *types* of work, and is credited with sending out total packages, but also criticized for still sending out work in bits and pieces. GM is seen as still primarily outsourcing in the body area, and not sending out programs, with a few notable exceptions. Again, these views are highly variable, and undoubtedly reflect the particular experience of each firm rather than providing a consensus view of the manufacturers. Even apparently contradictory reports, however, may be accurate. It may be that Chrysler, for example, does simultaneously send out more packages *and* more discrete bits and pieces work, simply because of rapid increases in outsourcing.

The manufacturers report somewhat less sweeping changes, both in scope and in rate. In their view, the outsourcing of total vehicles and of complete systems represents the major shift. Both of these developments involve reliance on the ES firm for performing a broader scope of design and engineering activities than has been the case in the past. For the most part, they view other changes as simply increased levels of, rather than fundamental changes in what is being sourced outside.

The traditional division of responsibility for design and engineering of a vehicle is undergoing some potentially major changes, and more engineering responsibility will go outside the OEM. A major source of uncertainty in this process is how much of this engineering responsibility will go to traditional, technically capable suppliers of parts and components, and how much to the specialty engineering suppliers.

We asked both ES and RMPC suppliers whether they felt that the increasing use of ES firms by the manufacturers meant that they would have less interest in the engineering capability of their traditional suppliers. All of the ES suppliers rejected this possibility, although for different reasons. Three pointed out that the supplier that manufactures the part is likely to have the specific expertise and competence required for the design and engineering of the part, while two others felt that the manufacturers would want to turn over the responsibility for a part or component to a single supplier, rather than separating the responsibility for engineering and manufacturing between two suppliers. Another ES supplier feels that the OEMs really want the manufacturing capability of the RMPC supplier reflected in the engineering.

One of the fourteen RMPC suppliers thought that the manufacturers' increased use of ES would mean that they would have less interest in the RMPC supplier's engineering capability. The rest thought it would not. Three, in fact, thought that this trend would *increase* the manufacturers' reliance on the traditional supplier, because it will "open up" the OEMs and because not only the OEMs but also the ES firms will have to rely on the traditional supplier for the engineering specific or particular to its product. One supplier pointed out that his company -- and many other traditional suppliers -- are perhaps narrow in their engineering and technical capabilities, but they are also awfully deep in their product areas.

The manufacturers made it clear that they want the engineering capability in their traditional RMPC supplier, and do not see the ES firms as feasible alternatives. Ultimately, they see the location of the technical capacity in their traditional suppliers as the way to maximize quality and minimize cost.

Factors in Outsourcing

We are particularly interested in how the decision to outsource engineering might relate to other factors, such as vehicle size, whether the manufacturer plans to make or buy the part or component, and the general push for modular sourcing.

The ES suppliers felt that there was no enduring relationship between vehicle size and whether the engineering work would be outsourced. Two suggested that there is a temporary relationship, reflecting the current levels and availability of small-car expertise outside the manufacturers. One of the manufacturers agreed with this, suggesting that the outsourcing for larger vehicles will likely increase. One manufacturer noted that the larger vehicles "... may not be as unique as we sometimes say they are." Another manufacturer suggested that there may be more derivative or adaptation engineering in small cars than in large, as parts and components are adapted to cover more platforms.

The ES suppliers split evenly on the question of whether the manufacturer' plans to make or buy the part or component are related to the decision to outsource the engineering. Three felt that the OEMs are more likely to do the engineering for something they plan to make themselves, although one noted that in some cases they also have sent engineering work outside, specifying that the product will be manufactured in their own facility. Three felt there was not much of a relationship between the engineering and product make-buy decisions, and one simply had no idea whether there is such a relationship. One of these suppliers pointed out that the engineering is often done before the final make-buy decision is made.

Two of the manufacturers think that they usually will do the engineering for a part or component that they make themselves. One, however, suggested that the manufacturers would come to rely on the ES firms for their in-house builds, and on the RMPC supplier (with or without ES assistance) for the engineering work for purchased parts and components. That pattern would certainly be consistent with a severe reduction in internal engineering headcounts at the OEMs.

The ES suppliers think that the manufacturers' push for modular sourcing has affected the ways they outsource their engineering. There is less consensus as to what this change is. One ES supplier sees it as a move to the traditional supplier base for the modules, requiring the ES to serve a new customer, while another sees it as a clear move to fewer, but larger, packages for the ES firms. One noted that he was sure that modular sourcing has affected engineering outsourcing, but really couldn't think of any examples. The manufacturers themselves note that they have been slow to move in this area.

Nature of the relationship

The rapid acceleration in the outsourcing of engineering suggests two possible models for how the industry might develop. One such model is the construction industry, where general contractors subcontract virtually *all* the specialty work, and act largely as the coordinator for the client's project. The other model is the legal model, where large law firms service most of the needs of the client, with only *occasional* farming out of specialty work. We asked the ES suppliers which of these models -- if either -- will more aptly characterize the engineering services industry by 1992.

Three ES firms felt that the construction industry model is more likely, one because he sees the needs for flexibility and cost-reduction as the basic drivers in the development of ES, another because he feels that the key role of the ES firm will be in assisting the manufacturers in integrating the diverse functions and activities involved in designing and engineering a vehicle, and the third because the OEMs will need a general contractor to monitor all the work in the face of their staff reductions. Three felt that the legal model will better typify the ES industry, primarily because of the fuller range of services that it implies. One felt that neither really is likely because the OEM will continue to act as its own general contractor due to concern over product liability, and the ES firm will continue to play the role of a subcontractor.

Among the manufacturers, one expects to see the legal model develop, while the other two anticipate a model closer to the construction industry, but with the manufacturer continuing to play the role of its own general contractor.

Both these models have risks. The construction model certainly offers flexibility and cost reduction, especially if the focus is on one individual job. But the cost reduction benefits may be only short-term, and the emphasis on them might in fact result in increased long-term costs. If the construction model involves the kind of competitive bidding and decision-making that characterizes the building industries -- virtually exclusive focus on cost -- then it may be that some of the dramatic engineering errors of that industry will be replicated in the automotive industry. The legal model suggests a level of dependence on the ES firm that the OEMs might find unacceptable, and might further complicate the integration of engineering and manufacturing activities.

The underlying point is that it is very unclear at this time exactly how much of the overall responsibility for engineering will continue to be within the manufacturer, and how much of it will be lodged in an ES firm, whether thought of as a general contractor or as a retained advisor. It is the allocation of this responsibility that will primarily influence the development of the ES sector in Michigan. The more of that responsibility that resides in the ES firms, the more value-added and decision authority they will have, and therefore the more critical will be their role in the automotive manufacturing chain, and the more substantial the wealth they generate. The less of that responsibility that is transferred to the ES firms, the more they will remain closer to the historic role of subcontractor and supplier of flexible capacity.

Because this transfer of responsibility is such a pervasive issue in the outsourcing of engineering, we posed the question of whether the manufacturers establish numerous checkpoints, or whether they simply examine the completed work. All the ES firms report that having numerous checkpoints remains very much the pattern of the manufacturers, some of them noting that there are major unresolved issues of product liability that make the manufacturers quite nervous about anything approaching full reliance on the ES firm. On the other hand, most believe that the manufacturers would *like* to transfer more responsibility than they have. One reports that they are still "heavy-handed" in their supervision, while another reports a gradual lessening of direction and the establishment of a "joint project" approach. One ES supplier notes that the level of direction is variable, and partially reflects the natural constraints that the job places on the ES firm: tooling design is constrained by the product, and so is less closely supervised, while relatively unconstrained product design is more closely watched. It is clear that the day of complete transfer of responsibility, the full "black-box" concept, is not imminent. One ES firm did note that, while the manufacturer might establish many checkpoints, it often would leave control of data and engineering change orders to the ES firm, and that certainly raises questions about whether the OEM really has control or the appearance of control. Another commented that while checkpoints are established, it can be very difficult to secure responses in the specified time because the OEM personnel are not available. Finally, one ES supplier suggests that the numerous checkpoints are the manufacturers' attempts to improve efficiency and to provide early identification of problems.

In a similar vein, the traditional suppliers report that the outsourcing of engineering responsibility to them has been slowed by resistance internal to the manufacturers. This resistance takes the form of failing to outsource, as well as complicating the outsourced work through increasing formal requirements in development, changes, and testing, and lengthening the time required for decisions.

One manufacturer notes that how fully it transfers responsibility to the ES firm has always varied, and always will. It depends on the product and on the ES firm's track record. Another suggests that, while it is moving to reduce the number of check points and locate them at critical stages, a process that relies only on final review is simply not going to develop. The third notes that they still provide day-to-day "observers" that do everything but direct the ES employees. That the level of supervision will always vary is undoubtedly accurate, as are the experiences and views of the traditional and ES suppliers. The problem is that no one seems to have a clear idea of what level of transfer is optimal, in general or for different types of projects, or for different suppliers. It does appear, however, that full transfer of responsibility to the ES firm is not likely in the immediate future.

A general issue facing the domestic automotive industry is the degree to which relationships between the manufacturers and their suppliers will become exclusive and/or long-term. The hypothesized benefits of such relationships -- efficient coordination of activities, increased attention to longer planning horizons, etc. -- would certainly apply to the engineering service supplier. Moreover, the heightened salience of proprietary concerns might make such relationships even more attractive to the manufacturers in the sourcing of design and engineering than in the sourcing of parts and components. Only one ES supplier sees any likely pressure for exclusive relationships developing, and one suggests that it might occur with some of the smaller outside houses. In the view of one ES supplier, pressure for exclusive ties would undercut the very benefits that the manufacturers seek from using ES firms, since it inevitably would raise their costs and reduce their flexibility. Five of the ES suppliers, however, see some movement to longer-term relationships, whether in general, with particular manufacturers, or more specific partnerships for particular projects. One supplier highlighted the mutual benefits of longer-term relationships: the ES can make capital investments and recruit better personnel, while the manufacturer secures continuity in the design philosophy and avoids the internal costs of repetitive bids. The two suppliers that see little likelihood of long-term relationships emphasized the cost reduction drive that underlies the OEM outsourcing of engineering. Two suppliers indicated that exclusive and/or long-term relationships create problems for the ES because it becomes dependent on one customer, and that customer can cancel its contract on 24 hours' notice.

The manufacturers see little pressure for exclusive relationships, citing the need for choice to ensure optimizing cost and quality. Long-term relationships may develop, but they are not drivers for the manufacturers. In contrast to the RMPC supplier base, the OEMs are not especially interested in reducing the number of ES suppliers that they currently have.

Changes by 1992

What changes or developments in engineering outsourcing might we see by 1992? All of the ES firms see changes that essentially will involve a broadened scope of the work that they will perform for the manufacturers. Some see this taking the form of providing services all the way through product design, prototyping, process design, and tooling right up to the initial build. Others feel that they are likely to provide more management and coordination services, without regard to exactly who performs the constituent tasks. Still others expect a more limited expansion, but expansion nevertheless. Some other changes include expanded servicing of the allied or captive supplier divisions of the OEMs, market consolidation in ES, and diversification away from automotive work into other manufacturing sectors.

The manufacturers primarily see the current trends continuing, with no fundamental changes developing. However, they do expect to see enginering increasingly coupled with manufacturing. The scenario for the development of ES that this suggests is one of more limited growth, and perhaps a contraction rather than an expansion of the range of services the ES firms provide, and a limiting of the range of parts and components that they design and engineer. How well the RMPC suppliers perform engineering may be the key determinant of what activities are placed at the ES firms.

IX. ENGINEERING AND MANUFACTURING

A major concern of the domestic automotive industry is the smooth integration of design and manufacturing activities. This involves the integration of manufacturing or process engineering with product design or engineering, and it also involves the integration of both of these engineering activities with the physical manufacturing of the product. Quite simply, we encounter difficulties because we often do not design a product for manufacturability, and perhaps more often do not design it to be manufactured in a particular facility, or design the facility to manufacture the product.

There is a broader underlying issue of the connection between design, engineering, and manufacturing. This is of particular concern to the State in assessing what the holding or attracting power of an activity may be for other activities. We addressed this issue in a number of questions in the interviews.

Product and Process Engineering

The first question raised the issue of whether automotive design and manufacturing engineering will be geographically closer or more separated by 1992. We prefaced this question by pointing out that one of the alleged advantages of the Japanese automotive industry has been its tighter integration of design and manufacturing activities, often by creating teams of manufacturing and design engineers that meet regularly, and by the assignment of manufacturing engineers to corporate and product engineers to plant locations. This has led some to speculate that manufacturing and engineering are likely to be done in closer physical proximity than has been the case. On the other hand, others have pointed out that electronic communications makes the world smaller, and could allow the physical separation of design and manufacturing.

Six of the ES suppliers feel that design and manufacturing engineering will be closer, although one suggests that this will involve multiple clusters of activity rather than one central location, and one notes that they are close now and will stay so. The data transfer capabilities of electronic communication are seen as solutions to relatively small problems in the broad integration of design and manufacturing engineering. One of the suppliers noted that satellite to satellite communication is fine, but it does not improve quality or reduce cost and time to market. The more important problems require face-to-face communication with the prints on the table.

The manufacturers also believe that these activities are likely to be geographically closer by 1992. One, however, noted that there is pressure to reduce duplicate capacity, and that this might run counter to the needs of functional integration, since it might require more personnel to functionally integrate in one location in the face of the dispersed manufacturing locations that already exist. Another suggested that the ideal solution to the integration of design and manufacturing engineering would be to have the same individual perform both activities, and if that is not possible, have two people within fifty yards of each other.

Engineering and Manufacturing

We also asked whether Michigan's relative advantage as the center of engineering service firms has any holding or attracting power for physical manufacturing activities. Four of the ES suppliers felt that it does not, that physical manufacturing will hold or attract engineering rather than the reverse, and that manufacturing costs are a greater concern. One supplier felt that it is a marginal advantage, but also noted that the direct costs of manufacturing are far more important. Two other suppliers felt that it does represent an advantage. One of these suggested that for it to have real leverage, Michigan needs to become a strong design center throughout heavy manufacturing, not just in automotive. This would facilitate the awareness and adoption of innovations from other areas by the automotive industry, as well as provide some insulation from the cyclical nature of the industry.

The manufacturers suggested that quality and cost are the real drivers, and that engineering has to be linked to strong manufacturing. Michigan has some problems here in overall competitiveness. One manufacturer suggests that the real link may be at the supplier level, as the traditional RMPC supplier finds that it must maintain a presence at an ES firm for the comfort of the OEM. This might influence future site decisions by such a supplier.

Sources of Engineering

Product and process engineering can both be done by the manufacturer or by the ES firm, or one type of engineering can be done by one and the other by the other. We asked the ES suppliers a series of questions about the quality of the manufactured product, cost, frequency, and difficulty of coordination of the four possible combinations of sources for product and process engineering. The thrust of these questions was to assess which combination ES suppliers see as optimal. The results were quite mixed. Three of the ES suppliers believe that doing both types of engineering in-house gives the manufacturers the cost and quality edge, and another thinks that is true for high-value components, where the manufacturer can more readily afford its higher fixed overhead. Three feel that doing both at ES firms provides better cost and quality, and one agrees for low-value components. One supplier notes that the advantages of the ES firm shrink as the size of the program grows, because it will be forced to duplicate the costly overhead and less effective management practices of the manufacturers.

The manufacturers feel that in-house engineering provides an edge too, although two would supplement it by the use of an ES firm. In fact, they report that outsourcing both forms of engineering is the combination most likely to result in a poorly manufactured product.

If we consider a part or component that is sourced from an RMPC supplier, then there are nine possible combinations of sources for accomplishing the product and process engineering because the RMPC supplier itself becomes an additional potential source for engineering. With one exception, the ES suppliers feel that the advantage in cost and quality is gained when the RMPC supplier does both forms of engineering. Moreover, they feel that this is likely to be the most frequent pattern by 1992. One ES reports that most cost-efficient is the combination of ES product and RMPC process, and that highest quality manufactured product will result from an ES product and an RMPC process.

The manufacturers agree that sourcing the engineering from the RMPC supplier provides a cost and quality edge over sourcing engineering either in-house or from ES firms. Two, however, think that participation by the manufacturer is important for fully realizing these benefits.

Finally, we asked whether close cooperation with an ES firm would help an RMPC supplier secure manufacturing business. All the ES suppliers felt that it would, although five indicated that this would be more true of a technically weaker RMPC supplier that used the ES to strengthen its own technical capacity.

Over half of the RMPC suppliers indicated that they felt cooperation with an ES firm might help them secure manufacturing business from an OEM. They felt that this could happen if the ES firm designed a "package" that fit their product, or designed a product particularly suited to their manufacturing processes.

The manufacturers felt that such cooperation might help the RMPC supplier secure business if the cooperation was quite close and both the ES and the RMPC supplier were good. One manufacturer suggested that, while this is a perfectly legitimate strategy, it might result in a little less confidence in the RMPC supplier.

X. ES DRIVERS

The automotive industry is undergoing a complex series of changes in its standard practices and the issues that it defines as competitively important. Many of these changes involve the standard business practices between the manufacturers and their suppliers, while others represent changes in emphasis or orientation. These changes range from an increased emphasis on quality to the introduction of Just-In-Time manufacturing and exclusive sourcing. It is clear that these broad changes constitute a web of changes, some tightly connected, others related only coincidentally. We asked the ES suppliers to consider a list of 14 such broad changes and to identify their importance to the OEMs' increased reliance upon outside ES firms.

We asked the ES suppliers to rate each of these changes on a scale ranging from "1" to "4", where 1 represented no, 2 little, 3 much, and 4 total importance to the OEMs' increased reliance on ES firms.

TABLE I
ES Firms' Views of Drivers for Increased Use of ES[3]

Source	Mean	Rank
Emphasis on Decreasing Manufacturing Costs	3.2	1
Shortening of Product Design Cycle	3.2	2
Emphasis on Decreasing Design Costs	3.0	3
Increased General Outsourcing	3.0	3
Reliance on Supplier Engineering	3.0	3
Supplier Involvement in Product Design	2.8	6
Increased Emphasis on Quality	2.5	7
Sourcing of Complete Modules	2.4	8
Standardization of Product Design	2.2	9
Multi-year Contracts	2.0	10
Exclusive Sourcing	1.8	11
Bid-free Contracting	1.8	11
J-I-T Manufacturing	1.8	11
Simultaneous Product and Process Engineering	1.8	11

[3]Respondents rated the importance of each source in the OEMs' increased reliance on outside engineering service firms. The scale is None (1), Little (2), Much (3), and 4 (Total).

Five of these more general changes were rated at least "3", and hence can be viewed as drivers of the outsourcing in the view of the ES firms. The outsourcing of engineering is in fact part of a broader increase in outsourcing as the manufacturers redefine their core tasks and seek improved cost and quality. The increased use of ES firms is a source selection issue within the more general decision to rely on suppliers -- both ES and RMPC -- for engineering. The remaining three drivers are more specific, involving a shortened product design cycle and reduced costs for both designing and manufacturing.

These data suggest two observations. First, for the most part, the ES firms tend to specialize in either product or process design, so it is not likely that the move to simultaneous engineering will be a driver for increased reliance on the ES firms. But virtually all respondents identified sourcing of product and process engineering from different sources as the combination most difficult to coordinate, whether for OEM makes or buys. Since simultaneous engineering is a concern of the manufacturers, this suggests that it may be somewhat incompatible with sourcing both product and process engineering from typically separate ES houses. Second, the high rankings of cost factors might suggest that the future of the ES industry will look more like the cost-driven construction industry. This has implications not only for the profit levels of the ES sector, but also suggests the range of services that firms might provide the OEMs and RMPC suppliers may be restricted, however broad they might be at the level of the industry.

XI. BARRIERS TO CAD

One of the more promising technological developments for the automotive industry has been the development of Computer-Aided-Design or CAD. This technology offers the opportunity to reduce costs substantially, through both the elimination of duplicate design work and labor-intensive drafting. At the same time, it offers the possibility of improved quality through the elimination of errors due to repetitive human processing of design iterations, and allows more design options for consideration within given time and cost constraints. The automotive industry has moved aggressively in the adoption of this technology, and the manufacturers have insisted on CAD compatibility as a requirement for their suppliers in the near future. CAD -- as hardware, software, and designer skill -- is an important part of the reason ES firms are being dealt a larger role.

We asked the ES and the RMPC suppliers to indicate how much of an obstacle each of a list of situation had been, or is expected to be, in realizing the full benefits of CAD. Table II displays these barriers, in the order that ES suppliers ranked them. The means for the ES suppliers and the RMPC suppliers are included, as are the rankings by the RMPC suppliers.

TABLE II

ES and RMPC Suppliers' Views of Obstacles to Computer-Aided Design[4]

Obstacle	ES Mean	RMPC Mean	ES Rank	RMPC Rank
Lack of timely technical support or documentation from vendors.	4.0	2.9	1	3
Difficulty interfacing with our own suppliers/subcontractors.	3.4	2.9	2	3
Insufficient personnel.	3.2	2.6	3	8
Lack of skills to maintain or develop CAD software.	3.0	2.9	4	1
Management's failure to set goals for use of CAD.	3.0	2.6	4	8
Lack of skills to operate CAD equipment.	3.0	2.3	4	13
Software inadequate for our needs.	2.8	2.9	7	3
Difficulty of identifying and measuring costs.	2.8	2.4	7	10
Resistance of design staff.	2.8	2.1	7	15

[4]Respondents rated how much an obstacle each described situation had been or was expected to be in realizing the benefits of CAD. The scale is None (1), Minor (2), Moderate (3), Major (4), and Absolute (5).

TABLE II, Continued

ES and RMPC Suppliers' Views of Obstacles to Computer-Aided Design

Obstacle	ES Mean	RMPC Mean	ES Rank	RMPC Rank
Difficulty interfacing with our customers.	2.8	2.8	7	6
Inadequate time allowed for implementation and training.	2.6	2.8	11	6
Difficulty of identifying and measuring benefits.	2.6	2.2	11	14
Equipment inadequate for our needs.	2.5	2.4	13	10
Our technical staff's lack of knowledge or experience.	2.4	2.9	14	1
Lack of skills to maintain CAD equipment.	2.2	2.4	15	10
Resistance of other staff.	1.8	1.9	16	16

The ES suppliers view only one of these obstacles as major, and five others as moderate. By contrast, the RMPC suppliers ranked all but one between minor and moderate. This compression of the rankings by the RMPC suppliers is consistent with other work we have done on the implementation of new technologies, including CAD. The specific profile of obstacles varies from company to company, so large-scale score differences among adjacent rankings occur infrequently. Since all but one of these companies has implemented CAD, the scale tends to be compressed: few respondents view any of the obstacles as absolute, and most respondents are reluctant to identify many of them as major. After all, the technology has been implemented with some degree of success.

The ES suppliers show more range in their rankings (4.0 to 1.8), and we suspect that this is because they have made larger investments in CAD, see its development as more central to their own success, and probably have experienced some problems that come with more exclusive and/or advanced use of the technology.

For the RMPC suppliers, the two highest ranked obstacles involve internal resources: lack of technical staff's knowledge or experience, and lack of skills to maintain or develop software. In view of the explosive growth in the use of this technology, this is not surprising: trained CAD operators are indeed in short supply. Unfortunately, allowing adequate time for implementation and training is not often seen as the appropriate response to this situation, perhaps because the lack of in-house preparation is not recognized until after the fact. Lack of such time is also among the higher ranked barriers. Problems with vendor support and software adequacy are both highly rated.

For the ES suppliers, the two highest rated obstacles involve external problems: lack of timely technical support and documentation from vendors and difficulty interfacing with suppliers and subcontractors. The ES suppliers in fact rate their own technical staff's lack of knowledge or experience fourteenth, in sharp contrast to the RMPC suppliers' rating of it as the most significant obstacle. This probably reflects their greater experience with the technology in-house, as well as their more sophisticated requirements for it.

Neither group of suppliers rates difficulty interfacing with customers or suppliers as much of an obstacle as one might expect. We suspect this is because there is little such activity occurring, rather than because it is not a problem when such interfacing is required. The Big Three have made a variety of announcements, including final dates in some cases, indicating that suppliers will be required to be CAD-compatible in order to secure further business. To date, these have not been enforced, and we suspect that the obstacle of coordinating with customers will escalate enormously should they be. Some of the respondents indicated that this is not yet an issue, and that CAD is used internally at this point.

It may be that the ES firms will be well-positioned to assist traditional suppliers as this technology becomes more widely exploited. Their experience in this technology may be complementary to the product engineering strengths of the traditional supplier.

XII. ES SELECTION CRITERIA

Supplier views of their customers' selection criteria can be useful in two ways. First, they provide a view of what the OEMs are truly emphasizing in their sourcing decisions, and that tells us something about what changes are occurring in the industry. Second, they suggest the suppliers' own premises for action, and that too provides insight into changes in the industry.

Table III displays the ES suppliers' views of the relative importance of a number of their own characteristics in the source selections of their customers. We asked for ratings from three time periods, ten years ago, today, and six years from now. While no comparative data are presented here, these questions parallel work reported in the 1985 AIM Report.

TABLE III

ES Firms' Views of the Importance of ES characteristics to OEMs[5]

Engineering Supplier Characteristics	Importance Past (1976)	Present (1986)	Future (1992)
Product Design Innovation	1.8 (6)	2.4 (9)	4.0 (4)
Process Design Innovation	1.6 (8)	2.8 (8)	4.0 (4)
Quality Performance	2.0 (5)	3.4 (5)	4.6 (1)
Delivery Performance	3.2 (2)	3.8 (4)	4.0 (4)
Short-term Price Quote	4.5 (1)	4.0 (1)	2.6 (10)
Long-term Price Quote	2.2 (4)	3.2 (6)	4.2 (3)
Financial Resources	1.8 (6)	3.0 (7)	3.8 (8)
Location Near OEM	3.2 (2)	4.0 (1)	4.0 (4)
R & D Investments	1.6 (8)	2.4 (9)	3.6 (9)
CAD Investments	1.0 (10)	4.0 (1)	4.4 (2)

[5]Respondents rated the importance of each engineering supplier characteristic to the OEMs for three time periods. The scale is Not Important (1), (2), Moderately Important (3), (4), and Extremely Important (5). For convenience, ranks are shown in parantheses.

Overall, these results suggest a supplier industry that in the past competed primarily on price, with delivery performance and location operating as secondary selection characteristics. This is certainly consistent with anecdotal evidence of the industry's past. Source selection today is far more complex, and all characteristics except short-term price quote have increased in importance. CAD investments have joined the three selection criteria of the past, and these four are nearly equal in importance. Looking to the future, these ES suppliers see an even more complex selection decision, with quality emerging as a basic competitive dimension, and short-term price being essentially replaced by long-term price. For Michigan, location continues to be important, but it is now one of seven, rather than one of three, important selection criteria.

These responses are quite similar to those of RMPC suppliers collected over the past few years. The ES industry was perhaps dominated even more than the traditional part and component supplier industry by short-term price, and that might account for its greater relative dominance in the past, and its declining importance since. (RMPC suppliers do not report declining absolute importance for short-term price, but increasing importance for other factors, including four that are rated as more important than short-term price in the future, two of these in the present.) ES suppliers see location near the OEM as more important than do traditional suppliers. On the other hand, the importance of quality in supplier selection is currently reported to be higher in the RMPC supplier industry. Cost, represented by short-term price, is currently ranked first in the ES sector, while RMPC suppliers already report the inversion of cost and quality that the ES suppliers expect to see in the future.

XII. MICHIGAN LOCATION

We asked the ES suppliers to identify any outstanding advantages or disadvantages there might be to a Michigan location for ES firms.

All the ES suppliers mentioned proximity to the OEMs as an outstanding advantage; for all but one, proximity was mentioned first. The available pool of automotive designers was mentioned by four of the suppliers, and quality of life by one. No other particular advantages were suggested.

The disadvantages to a Michigan location received much more careful listing. Five mentioned the Single Business Tax, four mentioned MESC rate setting policies, four mentioned Workers' Compensation issues, two mentioned the labor climate, and two cited a generally high cost base. The Single Business Tax elicited the most comment, as well as the most mentions. Labor-intensive industries feel disadvantaged by this tax, and ES firms in particular feel that they are not allowed treatment equivalent to manufacturers for their capital investments in identical computer equipment.

This section elicited other comments on State actions or inactions that really are not disadvantages, but merit consideration. One supplier was concerned about the assistance provided Japanese companies to locate in Michigan because this disadvantages his manufacturing customers. Another suggested that the State should provide more education in the technical areas that underlie design, and better education in the engineering areas.

The manufacturers mention proximity as an advantage, but one notes that the advantage is really for jobs that are sourced as bits and pieces. The larger the job -- the more "black box" it is -- the less important proximity as an advantage. This has been the case in outsourcing the engineering for the entire vehicle, where responsibility is more completely transferred to the ES firm.

The ES suppliers do not feel that the disadvantages of Michigan outweigh the advantages that proximity and the availability of trained automotive designers confer, with the exception of one supplier that appears to put more faith in the proximity-loosening potential of electronic communication.

A final issue emerged from our interviews, one we feel merits State consideration. If there is an emerging competitor for ES activity, it may well be Canada. Drawings are subject to custom's duty and delay; electronic data are not. This changes the basic economics of having design work done in Canada, and Windsor certainly shares much of the proximity advantage of the Detroit suburban area. Canada has currently made it quite easy for designers, especially from the UK, to secure entry and work permits, whereas the United States has not. In a crunch, as developed for a brief time last winter, that means that Canada can rapidly provide scarce manpower, and we cannot.

9/4/86

THE UNCERTAIN FUTURE OF MICHIGAN'S AUTOMOTIVE STAMPING INDUSTRY

(D. N. Smith)

Several factors identified in AIM I and II research indicate that the Michigan metal stamping industry tied to automotive markets faces structural upheavals. Examples of conditions signalling shifts include:

* Declining share of U.S. car production by principal customers of Michigan's captive and independent stamping plants--this production likely will be lost to Japanese/Korean car-producing plants opening in North America.
* New stamping companies from Japan are opening in U.S. principally to serve Japanese vehicle manufacturers; once open, these new stampers will sell to domestic vehicle manufacturers as well.
* Inexorable switch from stamped metal components to molded plastic parts.

To have a chance for survival, Michigan's stamping plants must raise productivity and quality drastically, while reducing costs. Virtually all facilities must be modernized. Stamping companies having annual sales less than $20 to $40 million will find it particularly difficult to amass the necessary capital. The purchase of a major automated press costs upwards of $1 million. New large transfer presses can cost several million dollars by the time they are fully equipped. Most Michigan stamping presses are 20 to 30 years old, indicating that a typical press plant will require several modern presses.

Just as there are concerns about the viability of the independently owned stamping companies, legitimate doubts exist regarding the future of captive regional stamping plants--some of which employ up to two thousand workers. They, even more than independent stamping companies, face threatening challenges to reduce costs and drastically improve quality. Additionally, captive stamping plants must shift from dedicated to flexible manufacturing systems.

Beyond equipment problems, captive stamping plants will need also to restructure their factory "culture." Management policies, restrictive labor demands, manufacturing process designs, etc., must be revolutionized to meet heightened world standards. Restructuring this "culture" in large regional stamping plants likely will prove so difficult that several will be unable to make the change, and will close. They will be replaced by greenfield operations using plastics rather than steel, or by independent stamping suppliers who have successfully modernized and restructured. Some of these suppliers will be transplanted plants from Japan; many will be outside the Michigan boundaries.

COMPARATIVE EFFICIENCIES

Evidence suggests that costs in the U.S. captive stamping plants are markedly higher than in the plants of comparable World Class competitors. The following approximate operating expense relationships are representative:

TABLE 1

INDICES OF RELATIVE COSTS IN METAL PRESS PLANTS
UNITED STATES AND JAPAN

U.S. Big Four U.S. Press Plants	100%
Independently Owned U.S. Press Plants	70% to 80%
Japanese-Owned Press Plants	65% to 75%

Sources: Industry interviews and analyses of comparative cost studies.

Japanese press plants appear to be about a quarter to a third more efficient than U.S. captive stamping facilities, and about 10 percent better than U.S. independent stampers. Cost comparisons cover major operational expense elements of labor, equipment amortization, steel, and equipment and tooling standards. These comparisons, of course, vary with fluctuations in Yen/U.S. dollar values.

Labor Costs

Labor rates in Big Four captive stamping plants range from \$26 to \$28 per hour, compared to \$12 to \$16 in independently owned U.S. stamping plants, and to approximately \$10 to \$16 in Japanese captive and independent plants.

Steel Costs

At the peak strength of the U.S. dollar, steel costs in Japan were estimated to be about one-fifth less than comparable steel costs in the United States. Now the two costs are comparable (Japanese Yen at 150-160). The consistency of the steel quality is still rated higher in Japan, giving Japanese press plants an important advantage in production efficiency and quality.

Equipment Expenses

Despite the obvious use of significantly more modern and expensive presses in the Japanese plants, equipment depreciation expenses are much lower in published detailed expense statements. Paradoxically, the interest expense category also seems comparatively small, considering the investments in modern presses. This might imply that Japanese industries have access to long-term, low-interest loans for modernization purposes.

Productivity

Throughput or productivity is a difficult parameter to measure and compare precisely, especially between two different plants producing somewhat different stampings; and also where each plant's output is being measured in local currencies that must then be converted through highly imprecise and perhaps artificial international exchange rates. While it is possible to make comparisons of production part counts at competing plants in separate countries, differences in product designs mean that all fenders, quarter panels, hoods, etc., are not created equally, which has varying effects on production rates. However, comparisons of total automotive press lines in Japan and in the U.S., after factoring in make/buy differences, disclose an enormous competitive efficiency advantage for the Japanese.

Inefficiencies over the total U.S. system of product and manufacturing process design and production activities comprise a fundamental component in the total vehicle cost disadvantage the U.S. automotive industry suffers relative to import competition. Japanese component designs are jointly evolved between product design and manufacturing engineers to promote production efficiency. The productivity results are impressive. Fully one-third of the U.S. body stampings' cost disadvantage is a direct consequence of ill-advised component designs by stylists and product designers unilaterally creating configurations that ignore manufacturability considerations. A common result is that U.S. body panels and related components require 7 to 8 presses for manufacture, compared to much less complex Japanese designs that are producible on as few as four presses.

Unless domestic companies move with dispatch to integrate their product/manufacturing process design systems, they likely will see a further deterioration of their cost disadvantage. To stand still will be tantamount to falling further behind. World Class vehicle manufacturers, responding to the strengthening of their currencies, are demonstrating surprising skill at wringing out even more costs from their already efficient systems. Further cost reductions are being achieved by jointly evolving production efficiencies with parts suppliers, including stamping companies.

Close and responsive liaison between Japanese vehicle manufacturers and their independent stamped parts suppliers, be they located in the U.S. or in Japan, is an important means by which the Japanese relentlessly drive down costs. Stamping companies serving Japanese vehicle assemblers in the United States indicate that their Japanese customers solicit and are much more receptive to suggestions regarding part design changes for economy purposes than are domestic vehicle manufacturers. One company suggests that it takes Big Four companies months for a committee to make a decision on a suggested part design modification compared to a week or two by U.S./Japanese customers--despite the need for engineers in the U.S./Japanese factory to obtain approval for the design change from the home office in Japan. It has been suggested that this kind of costly administrative delay increases significantly the relative cost of producing stamped parts for the domestic vehicle manufacturers.

Many attempts have been made to define the sources of today's $1,300 to $1,700 cost gap which is thought to exist between U.S.-built and World Class cars. Several companies have made a part-by-part cost comparison. A general conclusion that can be drawn is that, on most parts, the cost gap between the _landed_ price of World Class parts on U.S. shores and costs of comparable U.S.-built parts averages about 15 to 20 percent. Obviously on some parts there are few differences, and on others there are actually domestic advantages.

On stamped body parts the cost differential appears to be in the 25 to 35 percent range. However, not only does this cost comparison vary by part, it also varies between U.S. companies; some U.S. design/production operations for body components are more efficient than others. Chrysler, faced with bankruptcy in the early 1980's, seems to have responded by making impressive strides in this area.

In addition to avoiding complex part designs, there are several technical causes of the formed metal parts cost gap which must be addressed within U.S. stamping plants. Up to the present, World Class competitors have achieved their manufacturing edge in part through the rational and optimal deployment of proven conventional technology by a motivated factory management/workforce team. Just as in the past, future competitive advancements will not be achieved through isolated one-dimensional developments or disjointed tactical maneuvers, but through the continuation of refinements of a total coordinated system of business management practices. However, for discussion purposes, our research has somewhat arbitrarily "fitted" the technical advantages enjoyed by World Class stamping operations into three interdependent functions.

* Process Designs & Press Utilization
* Assembly & Welding of Quality Stampings
* Quick Die Changes

Selectively incorporating isolated practices from these functions likely will produce disappointing efficiency gains. However, when practices are implemented as part of an integrated system coordinating all functions--including product design activities--the <u>total</u> improvement is greater than the sum of the individual gains.

PROCESS DESIGN AND PRESS UTILIZATION

Simplicity is a term often used to characterize World Class metal forming/fabrication process designs. The engineered productive effort and equipment operating cycles are not vastly different from less efficient operations. However, process designs, which are finely honed by operating personnel on the production floor, minimize manpower, equipment, and facility downtime. Quick die changes and reprogrammable transfer automation provide critical flexibility. Faithful execution and control of process plans lead to efficient die changes and restarts, and minimal time delays between the last part and the first good one after a die change. Schedules are rationalized to reduce costly inventories of formed parts that are so susceptible to damage.

World Class press plants are smaller in size and therefore more manageable than the older plants used by U.S. companies. Typically the former have 10 to 15 press lines, and 4 to 5 presses per line. By contrast, captive U.S. plants have 15 to 30 lines, each with 6 to 8 presses.

An important shifting trend affecting the long-term viability of captive regional press plants is the practice in World Class vehicle final assembly plants to locate (right next to the assembly line) 3 to 4 highly automated press lines having only 4 to 5 presses each. These lines produce the vehicle's major body components. The advantages are so great that the vast majority of new assembly plants likely will include such stamping operations. Eventually, most major body panels will be stamped in vehicle final assembly plants, and phased out of regional plants.

In the past, there was little difference in the press technology or part transfer automation between the World Class and U.S. stamping plants. More recently the competitive leaders have accelerated the introduction of fully automated lines, requiring only half the direct labor of less automated equipment. Several World Class plants are installing computerized, self-contained transfer press lines capable of significantly enhanced productivity and quality standards. Such advanced automation likely will be commonplace in World Class press plants by the early 1990's, thereby impressively raising the competitive standards for both steel and plastic body parts.

Many World Class press plants outside the U.S. have been built in the past decade. Presses in these companies average less than 10 to 12 years in age, compared to an average age of domestic presses exceeding 20 years. Complicating the press age problem are inadequate U.S. equipment maintenance budgets and practices; these contribute to excessive equipment downtime in the range of 20 to 30 percent, compared to 5 to 10 percent in the leader plants.

An important result of presses properly maintained and dies clean and in proper alignment and working order is that stamped part surface problems are minimized. Among other advantages, this makes possible the elimination of part surface highlight oils, special lights, and extra labor to detect and resolve surface blemishes after press operations.

There are many other seemingly insignificant process concepts used by World Class companies that in total make a difference, such as minimizing the use of lubricants for the steel being formed--which later would need to be purged from the part surface before painting. To avoid lubricants, die surfaces are often hard-chromed to lessen friction between die surfaces and the part material. Dies also may be designed using guide plates with graphite inserts.

A common U.S. practice is to repair dies while they are installed on the press, keeping the press out of production. If a die breakdown occurs in production, the efficient press plant makes a quick die change and shifts the dies to the die maintenance shop for repair, while a different set of dies is installed on the press line in a matter of minutes for continued production of another part.

Not using production presses for die tryout is another World Class convention followed to maximize press line uptime. Following die construction, die tryout and adjusting are done in the die construction shop with all production aids installed in equipment identical to the production presses on which the dies will be used.

Most U.S operations perform initial die tryout (after construction) on the actual production presses on which the dies will be used, requiring that the presses be removed from production during time-consuming tryout. Individual variations in operating/maintenance conditions of aging U.S. presses often make it necessary to "tailor" die sets to compensate for respective press idiosyncrasies such as "ram" or gib inaccuracies, making it difficult to use another press for die tryout--even though it might be of the same make and model.

Considering the totality of the above efficient/inefficient methods, it is understandable that U.S. press operations seldom achieve uptime much in excess of 50 percent compared to 90 percent in World Class plants.

ASSEMBLY AND QUALITY OF STAMPINGS

The reliability and repeatability of World Class manufacturing processes assure consistent quality to high standards which not only reduce the need to inspect closely the surface of each part, but cut down on quality control inspections for other part parameters as well. Scrap rates are less than 0.5 percent compared to 3.5 to 6 percent (and higher) in less competitive press plants. Expensive rework of parts having marginal quality to save parts from being scrapped is considerably less. High-quality incoming steel to precise specifications tailored for particular families of part designs is also a key. Steel failing to meet the tight specifications is seldom accepted.

Besides being an important factor in final part quality, steel that does not conform to specifications creates serious direct cost penalties since material accounts for about half of the product's final cost. There appears to be about a five percentage point advantage favoring World Class press plants in utilization rates of steel--close to 75 percent, compared to 70 percent for U.S. plants. Non-utilized material results from scrapped parts, and from engineered scrap (generally, trimmed steel from a stamping and sheet steel separating the blanks/parts stamped from the coil).

Rejected part-scrap is minimized by consistently high quality steel which is effectively processed and controlled by well-equipped, committed management/ labor workteams. Engineered scrap is controlled by proper part design and engineering analysis leading to efficient layouts on the steel coil.

The value of consistent high-quality stampings manifests itself in downstream operations such as the assembly and welding of stampings into subassemblies and finally into the body. In downstream operations, World Class plants produce the same level of output with approximately 40 percent less labor. In many press plants having a fabrication activity, the fabrication/assembly labor accounts for a third of the plant's total labor force, thereby comprising a significant cost factor.

Despite attempts to restrict steel scrap, the still high rates even in leading press operations create an important economic advantage for plastic body components, which may have a process-scrap rate as low as a few percentage points, depending upon the application, process design and control, and the specific material specifications.

SIMPLIFIED TOOLING

An important criterion, not only in the struggle between competing steel press operations but also between steel and plastic materials is the comparative costs of dies/molds. Radically simplified tooling methods by World Class producers of body components create the following examples of efficiencies and savings:

* Fewer dies resulting from part/process designs that permit fewer presses to form the part.
* Simpler dies resulting from tightly controlled part design constraints, such as limiting part complexity.

* Die designs which incorporate welded trim and flange die edges.
* Flame-hardened upper flange rails rather than tool steel inserts.

Selective attempts to copy the light tooling standards, however, will lead to production breakdowns and poor quality unless other system elements are also incorporated. For example, press rams must be parallel with the bed; ram gibs maintained within proper limits, gearing tolerances within proper alignment; die set engineering must quickly provide for the reposition of the dies being installed to at least within $\pm$ 1/16 of an inch from the last die setup, etc. Light tooling standards also are effective only when used in an appropriately managed system of tight discipline regarding part design and manufacturing process control.

Compromises or breakdowns at any link along the chain will render light dies virtually useless. The inability of U.S. companies to control all the necessary subsystem elements from the initial phase in vehicle design through to the operation of presses has led to die design standards that depend on bulk and weight to overcome system abuses. Die manufacturing and operational costs increase even faster than weight.

The most striking visible characteristic of World Class dies is their light structure compared to the massive tooling used in press operations. Die castings typically weigh barely half of those used in U.S. plants. As an example, a door forming die may weigh 15,000 pounds compared to 30,000 pounds. Overhead cranes used to transport dies around a World Class press plant normally have a capacity limit of 30 tons compared to 50 in less efficient plants. The design of a single die to produce two parts, for example, a front and a rear door, is a common practice which magnifies the weight difference even more, effectively reducing the relative die weight to about one-fourth of the equivalent two dies required for U.S. door dies--normally designed to produce one panel per die.

Less complex and lighter tooling results in less costly tooling. The table below compares the cost of World Class tools to those used in less competititve press operations. For comparison purposes, the most expensive tooling (dies) are assigned a relative weight of 100 percent; the comparative cost of all other tooling is indicated as a percent of the most expensive.

TABLE 2

INDICES OF COMPARATIVE BODY DIE COSTS

Dies Built by Captive Shops, Heavy Standards	100%
Dies Built by Independent Shops, Heavy Standards	60%
Dies Built by World Class Companies, Heavy Standards	50%
Above Dies Delivered to U.S.	60%
Dies Built by World Class Companies, Light Standards	35%
Above Dies Delivered to U.S.	42%

Note: (1) The cost of delivering a die or a mold to the U.S. is estimated to add 20 percent for freight and customs duty.

The above tooling cost data, when evaluated in the context of comparative stamping/fabrication operations, strongly suggest that a major cost reduction possibility lies in adapting light tooling standards; 40 percent of the light die cost (35%) is added when the same companies build dies to heavy standards (e.g. 140% x 35% = 50% of heavy dies--see Table 2). However, as noted earlier, simply adopting the light tooling standards without incorporating all other system elements, such as proper equipment and tight product design restrictions, will produce little else than production breakdowns.

It would also appear that 40 percent of the cost of dies built to heavy standards could be saved by having U.S. independent toolmaking companies produce more of the dies, rather than the U.S. vehicle manufacturers' captive tool shops. However, too few independent U.S. shops have the necessary numerical control machining equipment. So, by default the captive shops may be left with few choices, other than to machine at least some of the die elements and assemble them or send them out to several independents.

An option is to buy the dies from World Class toolmaking companies offshore, which extensively use CAD/CAM with numerical control. Extended liaison links to offshore toolmaking facilities adds indirect costs and complicates the product design and manufacturing process engineering activities. There is also a question regarding the sufficiency of toolmaking capacity in World Class countries to supply their own needs as well as a substantial amount of new business from U.S. companies.

The American vehicle manufacturers' practice of designing their dies to comparatively tough and heavy standards was also a consequence of previously manufacturing very long part runs for car models with a substantial market potential. An example is the die requirements for the Chevrolet Impala in the late 1960's and early 1970's. During much of this era the Impala was being manufactured at a rate substantially above three-quarters of a million vehicles per year. Thus, the dies to stamp out the fenders, quarter panels, doors, etc. had to be designed and produced for extreme durability. Moreover, tooling costs, when amortized over this great number of parts produced during a 5- to 6-year product life, were relatively low, despite the high initial cost.

In this bygone era it was not unusual for experienced U. S. automotive manufacturing engineers to ridicule the "fragile nature" of light tooling which was quite appropriate for the little appreciated small production volumes characteristic of Japanese production in the 1960's. Now, however, the cheaper dies not only give the Japanese lower-priced parts, but the lower capital investment requirements are written off quicker, thus making it easier to economically justify retooling more frequently for new models. This advantage, then, helps provide increased flexibility and design leadership in the marketplace.

Higher than required die costs place regional stamping plants in double jeopardy when they are also compared to the cost of molds used to produce plastic automotive parts that otherwise might have been manufactured in steel stamping plants. Tooling investments comprise a very significant expenditure, and when they are amortized over smaller and smaller volumes for an increasing number of models, the resulting piece-part cost penalty begins to add up.

FLEXIBILITY FROM QUICK DIE CHANGES

Die changes in World Class plants are completed in 5 to 10 minutes compared to hours in most U.S. plants. Often, as many as three to four die changes are made each shift. In part, the quick die change concept is driven by "just-in-time" inventory/delivery requirements. Target inventory turns are in excess of 100 per year compared to 10 to 20 in U.S. body component-press plants. Quick die change (QDC) methods avoid inventories greater than a few days' supply--reducing inventory carrying costs, and eliminating part damage that increasingly occurs with longer storage periods.

Advantages of quick die changes, especially for production operations serving other than huge market niches, have been widely acclaimed for today's automotive markets. Even more flexibility will be needed as vehicle manufacturers move to consolidate their major panel stamping operations adjacent to final assembly plants. With modern stamping presses capable of producing panels as fast as 8 to 12 pieces per minute, sizable and costly inventories of stamped parts would quickly build since the final vehicle assembly pace is commonly one car per minute.

Many U.S. vehicle manufacturing companies, when they enjoyed much larger market volumes, accepted the costs of lengthy die change times as a price to pay for the benefits of long production runs. Now with production volumes reduced, and with major press operations moving to vehicle assembly plants, long press runs are an economic liability.

As in many other technologies, the efficiencies gained through quick die changes do not require substantially different equipment from that being used in domestic press operations. Many of the press plants in Japan using QDC employ presses based on U.S. and European machine tool design that is fundamentally two decades old. Of course, the Japanese subsequently made ingenious design refinements.

QDC depends more on modifications to die change methods and die/press attachment components, and is achieved through appropriately (not expensively) designed and constructed dies installed by precision-trained workers carrying out specific operations in an exactly timed sequence; an exercise that has been compared to the operational precision of a space rocket launch. QDC minimizes die/press adjustments during the installation of a new set of dies. Tooling is designed to shift all possible adjustments off the press and onto the die set. Adjustments are then completed to the maximum extent possible on the die set before it is placed on the press and while the press is still producing parts with the die set to be replaced.

In Big Four press plants the die adjustment process on the press consumes three-fourths of the four to six hours commonly required to change dies. A few examples of techniques to minimize adjustment operations are:

1. Standardizing die heights so that stroke adjustment can be avoided.
2. Standardizing die holder height so that the need to exchange fastening tools and adjustments can be elimi-

nated.

Beyond minimizing adjustments in die setting, time is saved by extreme routinization of the entire changeover process. Complete step-by-step process plans are developed. Everything is ready and in place when the press stops. Then, the thoroughly trained die setting team rigidly follows each step in the sequence.

QDC has proven to be an illusive goal for most Big Four regional stamping plants. Apparently, changing the culture that has developed and prevailed in the regional plants may be more difficult than introducing a radically new technology (e.g., plastics) that might achieve the same goal. At the heart of the problem is an ingrained management system supported by skilled trades practices that is slow to change. After all, such a system was the admiration of the world in the 1950's and 1960's, and apparently those managers and die technicians who played an important part in the development and refinement of conventions that were so successful for relatively stable car markets, find it difficult to accept and implement practices geared for flexibility.

This resistance to adopt new methods is not an uncommon reaction to change within large organizations. However, because the changes will be essential for future stamping plants, the continued preservation of antiquity will add more impetus to the trend to shift stamping operations to press plants integrated with the final vehicle assembly plant, or to independent parts suppliers. Another trend will be to switch to plastic parts manufactured in a new facility lacking the old culture--darkening further the future prospects of regional stamping plants.

PLASTICS' THREAT TO STEEL STAMPING OPERATIONS

Additional concerns about U.S. stamping plants' competitiveness and uncertainty emanate from a review of future new car plans which increasingly include plastic rather than steel body components. Captive regional stamping plants have produced parts almost exclusively from steel material. With a growing number of body panels and structural members in the 1990's expected to be plastic, another important impact on regional stamping plants will unfold.

There is little evidence to suggest that the new plastic body skin and structural parts business is targeted for the regional stamping plants, although some almost certainly will be. Molded plastic body parts are likely to be produced adjacent to the final vehicle assembly plant. It also appears that the automobile manufacturers will purchase a substantially greater amount of plastic body parts than they did for those parts in steel. This will be a significant new business opportunity for independent plastic molders.

However, the gain of the plastic molding industry will be a loss to the metal stamping industry, including both the captive and the independent plants. The latter are much more heavily represented in Michigan than are plastic plants.

Several factors influence the material selection for future automotive components. A very important one is the relative cost of U.S. tooling for stamping dies and the molds for plastic parts. Heavy and costly U.S. body dies create a penalty for steel and a liability for the stamping industry--see Table 2.

Domestic vehicle manufacturers make few of their molds. They buy them mostly from independent moldmaking companies in the United States or in Canada. Independent moldmaking and toolmaking companies enjoy a nearly 2 to 1 tool manufacturing cost advantage over those in the captive toolrooms of vehicle manufacturers. On this basis, the cost to produce a mold in an independent moldmaking company is about 50 to 60 percent of that which domestic vehicle manufacturers require to produce a set of dies for a comparable steel part in their captive shops.

It should be noted that at the current production rate of one plastic part every two minutes, and factoring in other parameters such as molding machine downtime, part rejects, mold repairs, etc., the productive capacity of a single mold typically has been constrained to less than 100,000 pieces per year. Thus, if the plastic part is to be assembled on a vehicle with a market potential greater than about 75,00 to 100,000 units per year, multiple sets of tooling could be required.

Impressive technological advances are occurring in plastic part manufacture. Based upon recent developments which are creating molded parts under ideal conditions at the rate of about 60 to 90 seconds, it is expected that one mold for a part which can be produced of a thermoplastic material, as an example, will be capable of satisfying production volumes up to about 140,000 vehicles per year. Tooling for vehicles selling above that volume level likely will require an additional mold, thus narrowing the cost differential with the competing die. However, a check of 1985 U.S. car sales illustrates that the bulk of future tooling needs will be for lower-volume models:

- Only four 1985 models sold by the Big Four exceeded 300,000 units.
- Sales of only seven bodies surpassed 400,000 units, which is roughly equal to the capacity of two assembly plants.

Regional stamping plants producing parts for the following models and their future replacements--if they continue to sell at volumes less than 100,000 units--could see some of their stamped steel components increasingly converted to plastic, and likely shifted to other sites for production:

AMERICAN MOTORS
- Renault
  - Alliance
  - Encore

CHRYSLER CORPORATION
- Plymouth
  - Caravelle
  - Gran Fury
- Chrysler
  - LeBaron GTS
  - Laser
  - New Yorker/E-Class
- Dodge
  - Daytona
  - Dodge 600
  - Lancer
  - Diplomat

FORD MOTOR
- Ford
  - Crown Victoria
  - EXP
- Mercury
  - Lynx
  - Capri
  - Grand Marquis
  - Topaz

GENERAL MOTORS
- Buick
  - Skylark
  - Skyhawk
  - Somerset Regal
  - Riviera
- Cadillac
  - Cimarron
  - Seville
  - Eldorado
  - Cadillac
- Chevrolet
  - Citation
  - Corvette
- Oldsmobile
  - Omega
  - Firenza
  - Toronado
- Pontiac
  - Acadian
  - 1000
  - Firebird
  - Phoenix
  - 6000
  - Grand Prix/Bon'vle
  - Parisienne
  - Fiero
  - Grand Am

Lincoln
Continental
Mark VI, VII

At even greater risk are stamping operations related to the lower-volume cars and which produce the following parts regarded as logical candidates for plastic:

Hood - Outer
Hood - Inner
Doors
Gas Tank
Bumper - Fascia
Bumper - Support
Fender
Supension Springs
Suspension Control Arms
Radiator Supports
Radiator Tanks

As noted above, the simplified tooling standards utilized by the Japanese for their dies almost eliminate the die/mold differential when the comparison is shifted from U.S. costs to those of the Japanese. Still, the use of light dies requires a total system modification, something U.S. vehicle manufacturers may be unable to achieve for at least ten years.

There are some very promising developments occurring in mass-cast tools using an epoxy resin process, as well as in final shape cast-iron tools. These methods have been under consideration because they have the potential of reducing die costs and tooling production time by about 50 to 80 percent.

A major attraction of mass-casting technology for tooling derives from its ability to cast to almost perfect final shape. Reportedly, on a few tools, no finishing operations were required before the cast tool was put into operation. When finishing is necessary, it is minor and not time-consuming.

G.M. reports that it cast 210 epoxy die sets in a period of three months compared to the 12 months that previously were necessary with conventional casting methods based on iron/steel castings.

Early application goals for mass-cast epoxy tools were restricted mostly to pre-production parts. However, one recent test by G.M. produced 20,000 wiper motor support brackets before the dies failed, indicating that with further refinements the process may have potential for low-volume production applications.

Such a breakthrough would have a positive impact on the ability of steel parts and stamping operations to compete with plastics and molding plants. This could occur despite the fact that mass-casting technology appears to be equally applicable to dies for steel parts and to certain molds for plastic parts.

As an example, if a conventional mold for a plastic fender can be produced for 50 percent of a hypothetical $1 million required to tool the same fender if steel were used, the $500,000 penalty when amortized over 50,000 steel fenders would amount to a $10 per fender premium. However, if mass-casting technology could be used on both the tooling for the steel and plastic fenders, and the technology creates a theoretical cost savings of 70 percent for both sets of tooling, then the cost penalty for steel fenders drops to only $3 per fender; an amount that is obviously more easily overcome with high-output steel press speeds as compared to relatively slow plastic molding rates.

Clearly, there are other factors to weight before deciding which material would allow the lowest body component production costs, but this discussion is intended to analyze just the comparable tooling costs because they have been mentioned so prominently as a major cause of some steel parts being switched to plastic when it comes time to tool up a new body or component. In such a limited comparative tooling cost analysis, it is clear that the successful development of mass-cast tooling would help slow the demise of Michigan stamping operations.

REVISED SOURCING PRACTICES FOR STAMPED PARTS

The extent to which die costs for steel parts can be reduced could affect the decline in business and employment prospects of the captive regional stamping plants. However, even if these tooling cost reductions achieve some degree of success, the net impact will be one of only reducing the rate of decline and the employment potential of the regional stamping plants.

There are several other cross-pressures which suggest that life at regional stamping plants will change, even for those that remain open. Increasingly buying rather than making parts which have traditionally been formed in captive regional stamping plants is expected to be one of the principal ways the auto companies will cut stamping costs.

As noted in Table 1, even U.S. independent stamping plants enjoy about a 25 percent cost advantage over the vehicle manufacturers' stamping plants. In the past, the regional stamping plants have attempted to compensate for their labor cost differential by keeping for their own production the extremely high-volume parts. With more models of smaller volumes being required in the U.S. marketplace, and with regional stamping plants finding it so difficult to make quick die changes, the efficient high-volume production methods of the regional stamping plants will become more and more difficult to exploit. Consequently, vehicle manufacturers are expected to buy more and more of these shorter-run stamped parts.

Stamped parts will be bought from traditional U.S. independent stamping companies, but also from foreign-owned stamping companies which already are here or will be coming to serve Japanese assembly plants located in the United States.

U.S.-based Japanese vehicle assembly companies are quite concerned because U.S.-produced stampings are considerably more expensive than those they are accustomed to buying in Japan. The U.S.-based Japanese vehicle manufacturers are encouraging their Japanese stamped parts suppliers to set up operations adjacent to the U.S. assembly plants. Some have already done so, and many more are expected.

Transplanted Japanese stamping companies find that they need to facilitize for efficiency purposes at a level above the current requirements of their Japanese customer in the U.S. They are also expected to find that the cost of producing stamped parts with light and inexpensive Japanese tooling, and with an integrated product design and production system, results in overall efficiencies compared to the typical U.S. system. These companies are beginning to approach the Big Four domestic manufacturers to solicit additional stamping orders for their unused capacity.

Some of these Japanese companies have bid on body stampings from domestic manufacturers. It is understood that, on the average, their quoted prices are about 20 percent less than the most recent prices paid by vehicle manufacturers to comparable independent stamped parts suppliers. Thus, intrusions by such Japanese stamping companies will not only have a major impact on captive regional stamping plants, but will also impact the independent U.S. stamping industry as well.

A change is also expected in the philosophy by which stamped parts are to be sourced to the regional stamping plants. In the past, a regional stamping plant may have specialized in producing doors, fenders, or hoods. These individual stamped parts were then shipped around the country to various assembly plants that would assemble the doors, fenders, or hoods onto the various models. It has now been demonstrated that this technique encourages the build-up of unacceptable tolerances and poor quality in the assembled body.

Rather than specializing in doors or fenders, stamping plants, whether they are captive regional operations or independent operations, will be assigned a more complete module of the body. For example, a stamping plant may do a complete front end for a particular car model or a truck. That plant will then have the responsibility for assuring the fit and finish of the entire module before it leaves.

Besides enhancing quality, there will be less of a requirement for expensive checking fixtures which are used now to verify dimensional consistency of the stamped parts. Under the new scheme, dimensional accuracy will be immediately apparent as the individual stamped components are assembled into the module right in the same factory. While these practices will redistribute stamping activities, they will not appreciably reduce the total amount of stampings needed.

The rationalization of production based on the assignment of a family of parts to the same plant for long-term commitments permits the Japanese captive or independent plant managers to justify a higher (but cheaper) level of automation, specially fitted to the relatively narrow characteristics of the family. This contrasts sharply with procurement practices of the Big Four, where contracts with independent stamping companies for stamped parts historically have been for a year at a time, with too little attention paid to channelling part families to particular independent companies, thus allowing them to automate for the narrow range of characteristics of their part family specialty.

In the absence of this specialization, independent companies have been forced to purchase relatively expensive general-purpose automation, that could be adapted to a broader array of part families that might be ordered by the Big Four in the future. Faced by these uncertainties and the absence of long-term commitments, few independently owned stamping companies in the United States enjoy the modern automation that is essential for optimal production. The penalty is not only increased labor requirements, but also lower quality.

SUMMARY

While U.S./Japanese comparisons may appear to indict the managers and technicians in U.S. stamping plants, in fact, many earlier shortsighted actions and decisions in vehicle styling and product/component engineering "come home to roost" in the stamping plant. It is important to distinguish between the root cause and the effect.

Some U.S. parts designs unilaterally created by stylists and product designers could not be produced economically at even the best of the World Class press plants. Solving the U.S. cost disadvantage on body-related components requires a total system approach--beginning with the styling activities.

The sad condition of U.S. presses is a testimonial to ill-advised short-sighted decisions by financial executives in U.S. vehicle manufacturers. The huge size of captive stamping plants represents a serious obstacle to change.

The total impact of all changes described above implies an uncertain, but most assuredly darkening, future for employees in Michigan's captive stamping operations. With increased outsourcing by U.S. vehicle manufacturers, independent stamping companies in Michigan stand to gain new business opportunities. They however will face-off in attempts to capture this business from new Japanese stamping companies opening across the U.S. Further, both captive and independent stamping operations are certain to lose business to plastic.

Considering the future loss to plastics, and the many existing competitive disadvantages captive regional stamping plants labor under--some of which are of their own making, or caused by financial executives or stylists and product designers--and considering the expected loss by the early 1990's of about 1.5 million car sales annually to new Japanese/Korean plants coming to North America, it is difficult to visualize a scenario which does not include the closing of at least six to ten major captive stamping facilities in Michigan. Many more smaller independent stamping plants also will likely close. But others will expand and some new ones--including a few from Japan--likely will spring up and prosper.

ALTERNATE ENGINE MANUFACTURING

STRATEGIES FOR THE 1990S[1]

Richard P. Hervey

Introduction

This paper is an attempt to begin a dialog among interested parties regarding alternative engine manufacturing approaches, the forces which will determine their selection and their implications on various Michigan constituencies: the automakers, suppliers, labor and local communities. It is part of a broader attempt to look at engine technology and related matters and their potential impact on Michigan, including investigations of market forces in engines, organizational issues, engine parts sourcing, engine design and development, basic manufacturing strategies, and key component technologies.

This "chapter" presents a series of hypotheses we are discussing in more depth with personnel experienced in engine manufacturing and marketing strategy. Based on these discussions, we are refining our hypotheses.

Driving Forces for Change

This paper is hardly the place to discuss all of the forces impinging on the North American passenger car and light truck markets during the last half of the eighties and into the nineties. However, it seems fair to predict that overall growth in total vehicle sales will be modest at best (say, 0.8 - 1% per year, on average). Competition will be fierce in all market segments, in part due to the effects of import and "transplant" vehicles.

[1] This is the first part of an ongoing AIM inquiry into engine manufacturing issues. The second phase of the inquiry is described in Appendix A.

Since they will be dealing with largely replacement, hence more discriminating, customers in an excess capacity market during some or maybe most of the next five to ten years, automakers will have to differentiate their products in order to carve out various niches. Volatility, both in terms of total market size and of segmentation and market share, will almost certainly increase as the industry moves through the transition to maturity.

Engines are, in most cases, not the commodities they were thought to be (at least by some) at one time. Increasingly, they play an active role in the differentiation process, at least with respect to some segments of the market. Thus, they must be managed as a key part of an overall product/market strategy.

Exhibit 1 shows certain elements of this situation and the resultant decision-making logic. The increasing importance of engine performance (which has many parameters) in consumer vehicle purchase decisions forces North American automakers to review their "stable" of engines with respect to their foreign competitors. Realistically, they find in many cases that our "horses" do not measure up in terms of performance/cost/durability tradeoffs. Thus the automakers conclude that a major part of their engine product line must be revamped to a larger or smaller degree (the former, if resources permit) over the next few years in order to maintain (against the moving target of competitors' engine developments) or regain competitive advantage.

North American automakers recognize that these engine programs will be launched in the competitive and volatile market environment discussed above. Furthermore, they understand all too well that engine development and facilitization is getting dramatically more expensive as we enter a new level of refinement demanded by more sophisticated potential buyers. They conclude that they must limit the number of different base engines they develop, maximize investment utilization and yet increase the responsiveness of the engine-making endowment to rapidly-changing marketplace needs and desires.

An understanding of these forces causes automakers to recognize that not only must they redesign many of their engines but at the same time totally reappraise their fundamental engine manufacturing strategy. Automaker management (and suppliers, labor, local and state governments) should be asking themselves some of the following questions:

1. What is the optimal engine manufacturing module size? How is this determined?

2. What components should be made in engine plants? Where and by whom should they be made if not in the engine plant?

3. What product requirements and manufacturing technologies are evolving that might change the answers to the foregoing questions?

4. What strategies best implement the answers to the above in such a way to best serve the market profitably?

5. What are the implications of these on the various constituencies involved? What can be done to smooth the transition?

In the following sections we attempt to offer alternative answers to these questions.

Optimum Module Size

The volatility of the market and the need for quick-response flexibility classically have not seemed consistent with high investment utilization. Longer-term trends in engine demand are shown in Exhibit 2. The first and second oil shocks completely changed the distribution of engine displacements installed in North American-built cars and light trucks. At times, for example after the Shah of Iran was deposed in 1979, it seemed as if only our offshore competitors could build enough of the engines that our consumers demanded.

But these longer term figures do not demonstrate some of the problems facing automakers in matching customer desires and effective engine building capacity in the shorter term. Exhibit 3 shows the year-to-year volatility in production of engines by General Motors, for example.[2] Note that while overall engine build declined by about ten percent between the two years, individual engine product lines grew as much as almost 29% or shrank as much as 42%. In fact, the year-to-year individual engine flexibility actually demanded by customers might well have been much higher, had capacity constraints (and, in at least some cases, CAFE concerns) not limited it.

This short-term volatility and the desire of automakers to serve the "fickle" marketplace are expensive. Sales and marketing personnel emphasize the large forgone sales and profit when

[2] G.M. was selected somewhat arbitrarily, although their complex engine endowment illustrates the point we are trying to make more clearly than either Ford or Chrysler with their more rationalized product lines.

potential customers must buy elsewhere because they cannot get the vehicle/engine combination they desire. This may indeed be the biggest cost, though we are not in a position to measure it.

However, we <u>can</u> look at another type of cost and the effect of module size and flexibility in Exhibit 4. If we assume that G.M. plans their engine capacity on an average daily production per-module capacity of 1600, then in order to meet 1984 demand, they theoretically needed 15 such modules. However, these modules are not fungible across different engines. If we count the minimum "indicated" number of modules in Exhibit 3, G.M. must have had a minimum of 18 engine modules operating during 1984. Thus, in 1984, they had no more than 84% capacity utilization, and conceivably less. (Given the inflexibility of today's engine-making capacity, G.M. managers must have been very busy rescheduling at that level of utilization.) With the overall decline and product mix changes in 1985, their engine capacity fell to no more than 76%.

If, however, G.M. had had engine modules rated instead at 400 per day, while they naturally would have had to have more of them, they would have been able (theoretically) to reach 95% capacity utilization in 1984 and to have stayed at 86% the following year. Of course, these smaller modules would have had to be more flexible than the larger ones in order to allow for product mix changes. However, it is unlikely that market shifts would have demanded more frequent capacity rebalancing (and hence module flexibility) than quarterly, and conceivably less often than that.

To oversimplify vastly what should be a much more complex calculation, if a 1600 engine per day production module requires an investment of $600 million (or about $1600 per engine of annual capacity), then with their increased utilization the smaller capacity modules could have cost about 17% more per unit of annual capacity and yet required only the same total investment. In addition, since these more flexible smaller modules could have been redeployed to match market demand better, using them could have resulted in fewer lost sales and hence in increased profits.[3]

[3] We hardly pretend that this is a very scientific way to discuss this matter. For example, piece cost penalties, the time value of money and various probabilistic factors should be brought into the analysis. Perhaps we can use that more sophisticated type of model in a later edition of this paper. For now, we are simply trying to illustrate the importance of these issues.

Every capacity planner knows these matters very well. If there were no penalties to shrinking module size, we would all use a number of modules equal to annual production, each one of which had a capacity of one. The real world obviously isn't that way. However, one of our key questions is whether manufacturing technologies have changed, and will change, such that the penalties, and hence the optimum module size, should change as well.

In our discussions with Big Three personnel, we have received a wide range of opinions. One school of thought is that engine investment costs are such that larger, but somewhat more flexible, modules are indicated. Another camp feels that flexible manufacturing technology and its cost are progressing at such a rate that there will soon be few or no penalties to using many small, highly flexible engine production modules. Both groups are thinking of using CNC and DNC concepts (including higher-level supervision of the factory equipment), but are implementing these concepts in very different ways.

We are hardly expert enough to appraise the technical/economic wisdom of these two extremes (let alone all of the combinations between them), especially without proprietary operating data and estimates. However, we will try below to describe how these different views might look and what they might imply for Michigan.

Manufacturing Content in the Engine Plant

Traditionally (and very naturally), engine plant managers tried to retain under their own control, usually within the plant itself, the production of as many as possible of the components which made up the engine. This was often determined on a "trade" basis: if it was machined or ground or assembled, the engine plant would make it, while if it was cast or forged or stamped or molded, it was bought by the engine plant, often from captive operations within the same automaker. This situation is pictured in Exhibit 5.[4]

Note that many components, central and peripheral, were made within the engine plant itself, normally of raw castings and

[4] This and subsequent exhibits are highly stylized. Obviously, it is impractical to show all of the many parts which make up an engine. Furthermore, the several automakers, and even different engine operations within a given firm, differ in their approach to engine component sourcing and manufacturing. However, these exhibits are generally indicative of the changes taking place.

forgings made in captive foundries and forges. This was not surprising, as making an engine is a high precision process which, at the time, required such integrative functions as selective assembly. This meant, however, that when a new engine plant was required, it had to be sized with all of the peripheral machining/subassembly included. This also required engine plant personnel to be expert in the machining and assembly of many different types (and sizes) of parts, in quite diverse materials.

Even as early as the 1970 era depicted in Exhibit 5, some of the manufacturing content was being removed from the engine plant. As emissions control regulation came into force and the engine (and hence engine manufacturing) became more complex (often requiring more floor space), several peripheral components (e.g., water pumps and oil pumps) were moved outside the engine plant, usually to captive parts machining plants. This trend has continued to some extent, to where today (Exhibit 6) more of the content at the front end of the engine is performed outside the engine plant.

In addition, more of this component manufacturing is being done outside the automaker itself. In part, this came from the introduction of new materials, design and production technology, the capability for which was stronger in firms specialized in making that particular component for several customers. However, in part this trend reflects a realization by automakers that the cost of outsourced engine parts was often lower than that of captive "raw materials" (e.g., foundries) and machining plants. This cost saving derives partially from lower labor and overhead costs outside the Big Three and partially from the aforementioned economies of the specialization. These outside operations are often organized on a product line rather than a trade basis, for example, casting and machining pistons rather than casting and machining many diverse parts.

We think that this tendency will continue and probably accelerate as the next generation of engine technology is facilitized. Thus we predict the situation shown in Exhibit 7: in the future only core (usually large) components are actually machined in the engine plant itself. Both technology itself and particularly the application of statistical process control now allow far more interchangeability of parts and the elimination of selective assembly. Beyond the physical aspects, S.P.C. offers the plant manager the peace of mind that suppliers outside his immediate control will make easily usable parts. Outside parts can be "trusted".

Engine component design and materials selection are becoming more demanding, often requiring more specialized facilities. For example, camshafts are moving from iron to steel as roller lifters are introduced to lower engine friction. There are various ways being tried to manufacture these more difficult camshafts. However, they all share the characteristic that the highest quality, lowest cost way to make them requires integrated process control and optimization among various trades (forging and machining, for example).[5] Techniques for processing these high-tech engine components are often so specialized that they are best developed and implemented by experts in those areas who can then prorate the development cost and specialized facility investment over several automaker customers.

We predict that more of these component families will be manufactured outside the auto companies. In part, this comes from the labor cost and overhead differentials discussed above. However, a perhaps equally important reason is that independent companies typically are more motivated and flexible with respect to development and refinement of these highly specialized, even arcane, products/processes. These products/processes are proportionately more important to these specialty firms than they are to the automakers.[6] We see this as a natural extension of an emerging trend by automakers to outsource anything that they can without sacrificing world-class design, quality, and cost.

Because this type of approach has been quite common in Europe, it appears that a significant part of this outsourcing, although by no means all of it, will be placed with foreign firms. Some of these specialized foreign manufacturers of engine parts have already built manufacturing facilities in the U.S. How many more will do so remains an open question, but we assume that recent currency realignments make this more likely. Obviously, this is an opportunity that Michigan cannot ignore.[7]

[5] See, for example, American Metal Market/Metalworking News, January 13, 1986 and March 31, 1986 for discussions of two new camshaft approaches.

[6] There are obvious exceptions within the automakers. See, for example, American Metal Market/Metalworking News, Feb. 24, 1986 and Ward's Engine Update, April 1, 1986. However, these units, which are often at risk for various reasons, often have difficulty attracting the technical and capital resources required to do a world-class job in these areas.

[7] See, for example, American Metal Market/Metalworking News, Feb. 17, 1986, March 24, 1986 and April 7 and 14, 1986 and Ward's Engine Update, April 15, 1986 regarding domestic vs. foreign outsourcing of pistons. See American Metal Market/Metalworking News, Jan. 6 and 27, 1986 and Feb. 24, 1986 regarding domestic and foreign outsourcing of head castings and finished intake

Thus, we predict that the engine plant of the future will have fewer different operations within it. It will focus on making fewer parts better and especially on developing flexible assembly systems allowing rapid, low-cost response to changing customer needs.[8] They will optimize the core (head and block) engine-making process, while counting on outsiders to optimize (perhaps on an entirely different level) the manufacture of other high-tech components. The alternative would be for engine plant management to sub-optimize more of the engine content, something perceived as putting them at a competitive disadvantage today.

Alternative Models for the Future

Several elements must now be integrated to discuss alternative future models for engine production. The phenomenon of removing certain manufacturing operations from the engine plant itself seems clearly under way. There may be some debate as to the rate and destination of this outsourcing (viewed from the engine plant), but little about the direction. This is particularly true with fundamentally new engines.

On the other hand, there is still a great deal of uncertainty as to whether the ideal module size (discussed above) is growing or shrinking. The growing case is pictured in Exhibit 8. The shrinking case is represented by Exhibit 9.[9]

manifolds. Note that all of the foreign sources mentioned in these articles are European, not Japanese.

8 Engine plants may, for reasons which will become clearer below, add "tail end" operations, such as "dressing" the engine (which is already done in a few cases). Since once an engine is "dressed" it is often suitable only for a specific customer order, this requires that the dressed engines be "in-line sequenced" for final vehicle build. This requires better inventory and quality control, as an assembly plant build can be disrupted by any in-line sequenced subsystem which is incorrect for any reason, requiring the vehicle to be pulled off the line.

9 There is a third school of thought which says that little is changing in engine-making technology, at least not enough to justify new investment. In part, this is justified by the perceived lack of change in engine manufacturing strategies by the Japanese. For now, at least, we will ignore this school of thought as it implies fewer net effects on the future, other than loss of market share if it is erroneous.

The "Focused Concentration" model of Exhibit 8 assumes that the technology/economics of engine building are evolving such that closely related engines should be manufactured (for core parts) and assembled in large plants serving all of the assembly plants using that engine. Each of these plants might be flexible enough to make variants of the same basic engine (as is often the case today) or even somewhat more different engines.[10] Depending on the engine mix needs of the automaker, these plants might become somewhat or much larger (in terms of capacity). They would be far more flexible than today's plants, which might require some compromise in engine design and certainly in processing optimization.

The "Contiguous Manufacturing" model of Exhibit 9 follows many of the trends in that direction implied by such concepts as Just in Time. Here it is assumed that the incremental costs of many small engine-building modules, each set up to serve one (or a selected few) assembly plant, are outweighed by increased customer responsiveness and minimized inventory cost. Furthermore, engine plant management might identify more closely with the assembly plant's requirements in serving customers.

These small modules would have to be quite flexible, although perhaps less so than one might think if the investment/operating penalties involved are small. Although the basic concept would be to serve one assembly plant with one or more engine modules, one would want to provide for interplant shipping as well, as shown in Exhibit 9, where Engine Module C-1 ships not only to Assembly Plant C but also to Assembly Plant B.

Presumably, the choice of one or the other of these strategies is dependent on an appraisal of the specific automaker's vehicle/engine mix and of the investment/operating cost penalties implied by the smaller modules. Note that these parameters would have to be estimated at least 3 years (the bare minimum lead time, probably, for strategy implementation) to 10 years out (the probable "half-life" of the strategy, although not necessarily of the engine in question).

Clearly there is room for a mixed strategy in some (or even many) cases. Large "base load" plants might be supplemented by smaller "swing" engine plants which would provide the necessary flex in the whole engine supply base. We assume that this approach might

[10] Apparently this is the approach being suggested by the Ford executive interviewed in Automotive News, April 7, 1986.

be taken if a manufacturer feels that the penalties of small modules are still large, but that large plants (for technical or organizational reasons) are still too inflexible. Once again, forecasted engine/vehicle mix will be a key decision determinant.

Two further comments are in order in this section: First, the "pilot" engine manufacturing plants announced by several automakers in the southeastern Michigan area[11] have an important role to play. Not only will this development serve its obvious purpose of more quickly building prototype or pilot engines or permitting the low-volume start-up of engines being tooled, but they should provide an invaluable test-bed for the small module concept. At the moment, we have few data points (in automobile engines, at least) between laboratory concepts and large engine-building modules.

Second, the configuration and certainly the location of the engine component-making infrastructure will almost certainly be dependent on which strategy is chosen by the automakers. If there are fewer, somewhat clustered engine plants as the "Focused Concentration" model implies, then one can anticipate fewer, somewhat clustered parts plants. The "Contiguous Manufacturing" model does not necessarily portend the opposite, but it certainly changes many of the strategic and tactical variables for parts-makers.

Implications for Automakers, Labor and Suppliers

All of the scenarios discussed above have effects on the various constituencies' interest in engine and vehicle building in North America: even a "No Change" scenario would have major impacts. If we are correct that some sort of change is necessary, in fact, "No Change" would probably mean a greater loss of market share by the Big Three, with all that that would imply. In fact, one can argue that that is the alternative with the highest risk.

It is the automakers that will eventually, piecemeal or otherwise, decide on fundamental engine product and manufacturing strategies. It is very likely that different strategies will be appropriate for each of the Big Three, depending on each firm's current engine-building endowment, future market position, and capital/human resource base.

The potential impact on labor is enormous, regardless of the strategy chosen by the automakers. Although engine manufacturing

[11] See, for example, American Metal Market/Metalworking News, March 31, 1986.

itself is not as labor-intensive as other parts of car building, increased productivity will inevitably mean job loss. Furthermore, the two polar models discussed above (or the mixed strategies available) mean that many engine plants will be located in different places than today.

In addition, engine parts outsourcing to non-Big Three plants will probably mean a different split of union/nonunion workers and UAW/non-UAW. Even a transfer of work from engine plants to captive parts plants usually means that different workers are employed. Furthermore, there is a significant question whether many parts can be redeployed to captive parts plants without significant concessions by the employees in those plants.

Beyond the quantitative effects on labor, there are several important qualitative ones. For the work which remains in engine plants, capital utilization will become a much more vital element in the profitable operation of the plant. This will increase pressure for changes in work rules in existing plants or investment in new plants (either "greenfield" or "radical brownfield") where capital utilization is assured by a more "cooperative" workforce. Skill levels of remaining jobs will almost certainly increase. The ability and willingness of work crews to keep their equipment working with minimum delay is vital to both the Focused Concentration and the Contiguous Manufacturing models, although for slightly different reasons.

Suppliers also stand to be impacted greatly by these changes. For independent suppliers, significant business opportunities will be presented. The choice of suppliers will depend in large part on which step up soonest and best to the increasingly complex (and, probably, capital intensive) task of managing a vertically integrated supply of a whole "function" within an engine. (This is no different than what is going on in the supply base in general.)

Captive suppliers (and non-vertically-integrated lower level independents as well) face a particularly difficult challenge. They have both offensive opportunities and defensive risks. A captive foundry, for example, will probably have less chance of capturing an independent machining company's business than a sister engine plant's. In fact, even captive upstream parts plants may increasingly have to look to independent "raw materials" suppliers if they are to remain competitive. Thus, we would think that the "lowest level" captive plants, i.e., foundries and forges, are in the worst position. It is not clear what combination of changes in management approach, labor cost and capital investment might save these businesses, if indeed they can be rescued.

The choice of Focused Concentration or Contiguous Manufacturing may affect different suppliers in different ways. All things being equal, we would think that the former favors captive suppliers to some extent while the opposite is true in the latter.

A special discussion is demanded with respect to engine machinery suppliers. Here we are concerned with those who make both machining and assembly equipment (and all of the support equipment which go with both). To the extent that engine parts are outsourced to non-captive suppliers (especially European firms, even if manufacturing in the U.S.), it seems reasonable to assume that machinery buying preferences will change. Machine tool suppliers will have to change their product lines and their marketing approaches to serve these new potential customers.

The portion which remains within the automaker, even within the engine plant, will also pose serious challenges to machine tool makers as well. The need for flexibility implied by either of the strategy alternatives described above requires considerably different equipment than has historically been provided by the Big Three's traditional machine tool suppliers. Automakers are concerned about the ability of American suppliers to provide what is needed. In fact, much engine building machinery is already being procured from foreign firms, although there is sometimes fairly high American content in these systems.[12] Further, the choice of the Focused Concentration or Contiguous Manufacturing models may have a major effect on particular machine tool and machinery suppliers, since a given firm is not necessarily equally competitive on these necessarily different types of equipment.

Michigan Considerations

Michigan has a disproportionately large share of North American engine and engine related production (as compared with final vehicle build distribution)[13] and of related machinery and equipment capacity. Hence, Michigan stands to be affected dramatically by the changes discussed above.

Given change, Michigan probably has more to lose than to gain, since it is hard to conceive, on balance, of the state gaining more engine and engine-related capacity, even under the "Focused Concentration" model. However, it is clear that this alternative

[12] See, for example, American Metal Market/Metalworking News, Mar. 10, 1986 and Ward's Engine Update, April 15, 1986.

[13] Michigan plants assemble about one-third of the Big Three's U.S.-made cars and light trucks but manufacture nearly two-thirds of their engines, automatic transmissions, and major body panels.

is far more desirable for Michigan than the "Contiguous Manufacturing" model, given the distribution of assembly plants around North America.

In both cases, State government can probably help its competitive position by a proactive training and education program preparing engine plant workers for the more technically demanding jobs in tomorrow's engine plants. A good offense is the best defense.

The picture is potentially, though not necessarily, brighter in the engine parts area. Here there may be some room for action by State government in assisting suppliers to find missing technology, to establish their own chains of supply, etc. For example, the state could assist local engine parts suppliers in licensing-in or joint-venturing engine part-making (and/or machinery design/construction) know-how, probably from European partners. On the other hand, the parts business is probably more labor-intensive than engine-building itself and thus Michigan may be at some disadvantage.

It is probably the communities that are home to captive "raw materials" and engine parts plants that risk being most adversely affected. These are focused around the Flint/Saginaw Bay area, as well as in Detroit and Dearborn. Special effort should be made to understand the situation of plants in these areas, and special targeted policies explored.

* * * * *

Clearly, much will change in engine-building and related areas in the coming decade. Michigan is in a pivotal position with respect to these changes. Although it appears that the net effect of these may be negative for the state overall, anticipation of change and active participation in "sculpting" the implied transitions can minimize the dislocations and maximize positive outcomes where they are realistically possible.

APPENDIX A:

Next Steps, AIM Engine Inquiry

2. "Core" Components, Technology and Sourcing
   - Cylinder Blocks
   - Cylinder Heads
   - Intake Manifolds
   - Exhaust Manifolds

3. Moving Parts
   - Camshafts and Other Valve Train Parts
   - Crankshafts
   - Connecting Rods
   - Pistons

4. Service Functions
   - Water Pumps
   - Oil Pumps
   - Accessory Drive

5. Engine Electrical
   - Starters
   - Alternators
   - Engine Wiring
   - Spark Plugs

6. Fuel System, Controls, Miscellaneous
   - Fuel System
   - Engine Controls
   - Miscellaneous

7. Strategic Options for Engine Component Manufacturers
   - New Products and Processes
   - New Customers and Channels
   - New Competitors

8. Implications for Michigan
   - Engine Plants
   - Captive Engine Parts Plants
   - Independent Parts Plants
   - Foundries, Forges

Exhibit 1

Decision Path

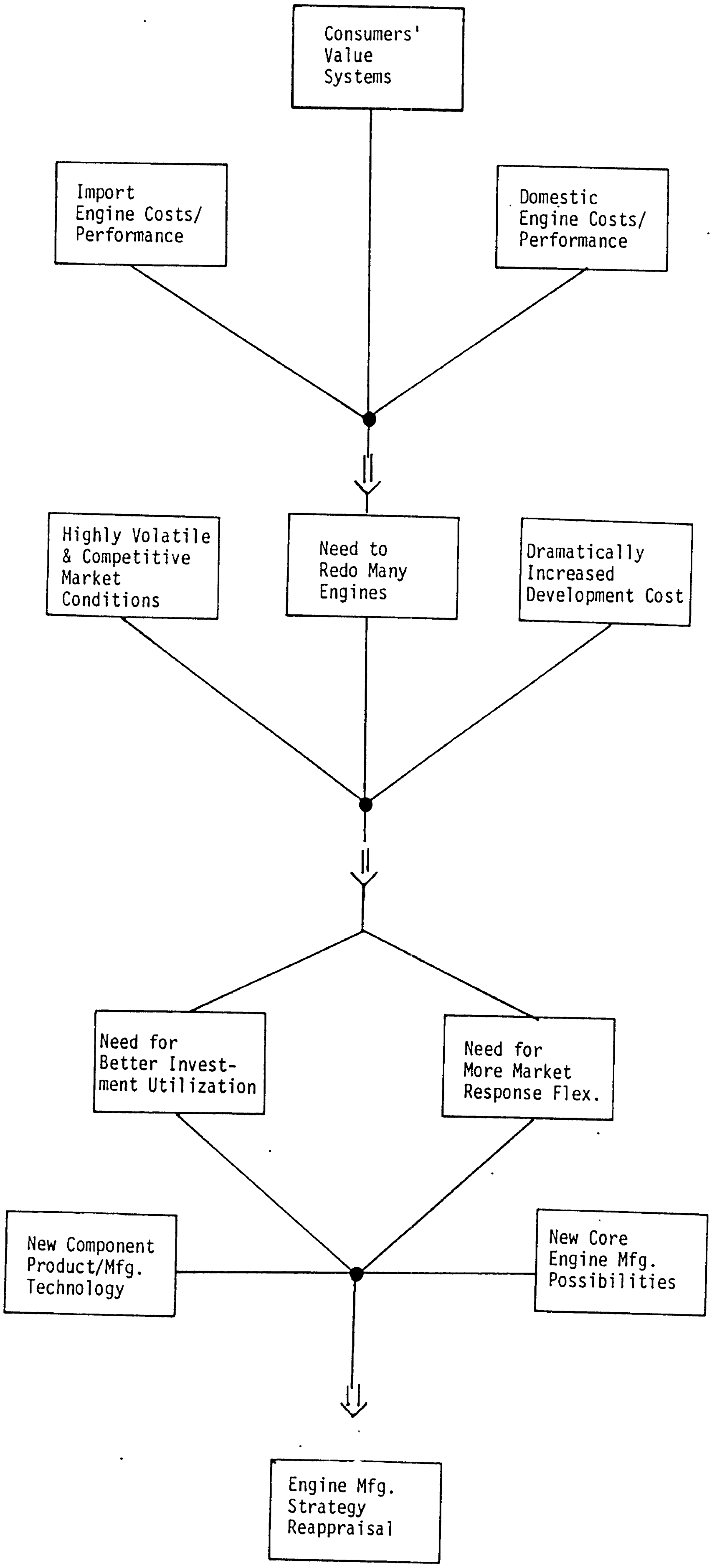


Exhibit 2

Engine Displacement Trends: 1973-1985

	Model Year	Up to 200 CID (3.2L)	201-250 CID (3.2-3.9L)	251-300 CID (3.9-4.7L)	301-350 CID (4.7-5.5L)	More Than 350 CID (5.5L)
	1985	57.8%	17.3%	1.5%	23.3%	0.1%
	1984	56.1	18.6	0.9	24.2	0.2
	1983	49.6	20.6	2.0	27.6	0.2
	1982	53.3	17.6	7.8	21.0	0.3
	1981	51.1	19.6	9.9	16.7	2.7
	1980	45.4	20.0	11.0	19.7	3.9
2nd Oil Crisis	1979	26.7	13.7	7.5	40.4	11.9
	1978	16.8	16.2	5.1	40.9	21.0
	1977	7.2	15.7	2.0	47.5	27.6
	1976	11.7	17.6	4.1	35.8	30.8
	1975	10.1	15.8	5.2	33.9	35.0
	1974	16.0	13.6	1.8	34.5	34.1
1st Oil Crisis	1973	9.3	8.4	0.9	39.5	41.9

Source: Ward's Automotive Reports

Exhibit 3

G.M. Gasoline Engine Production
(Thousands of Units)

Type	Displacement	1985	1984	Unit Change	% Change
4 cyl.	1.6	175	290	(115)	(39.7)
	1.8	161	279	(118)	(42.3)
	2.0	469	606	(137)	(22.6)
	2.5	691	537	(154)	28.7
6 cyl.	2.8	616	643	(27)	(4.2)
	3.0	341	316	(25)	(7.9)
	3.8	682	790	(108)	(13.7)
	4.1	---	32	(32)	(100.0)
	4.3	104	---	104	NA
8 cyl.	4.1	327	321	6	1.9
	5.0	1109	1364	(255)	(18.7)
	5.7	52	47	(5)	(10.6)
	Totals	4727	5225	(498)	(9.5)

Source: Ward's Automotive Reports

Exhibit 4

Stylized Capacity Calculations - G.M.

	1985	1984
For Module Size = 1600/day		
"Ideal" Number of Modules	13	15
"Indicated" Number of Modules	17	18
Capacity Utilization if 1984 "Indicated" is Correct	76%	84%
Reserve Capacity (Thousands of Units) if 1984 "Indicated" is Correct	1497	999
For Module Size = 400/day		
"Ideal" Number of Modules	52	57
"Indicated" Number of Modules	54	60
Capacity Utilization if 1984 "Indicated" is Correct	86%	95%
Reserve Capacity (Thousands of Units) if 1984 "Indicated" is Correct	793	295

Exhibit 5

"Classical" Engine Build (late 1960's)

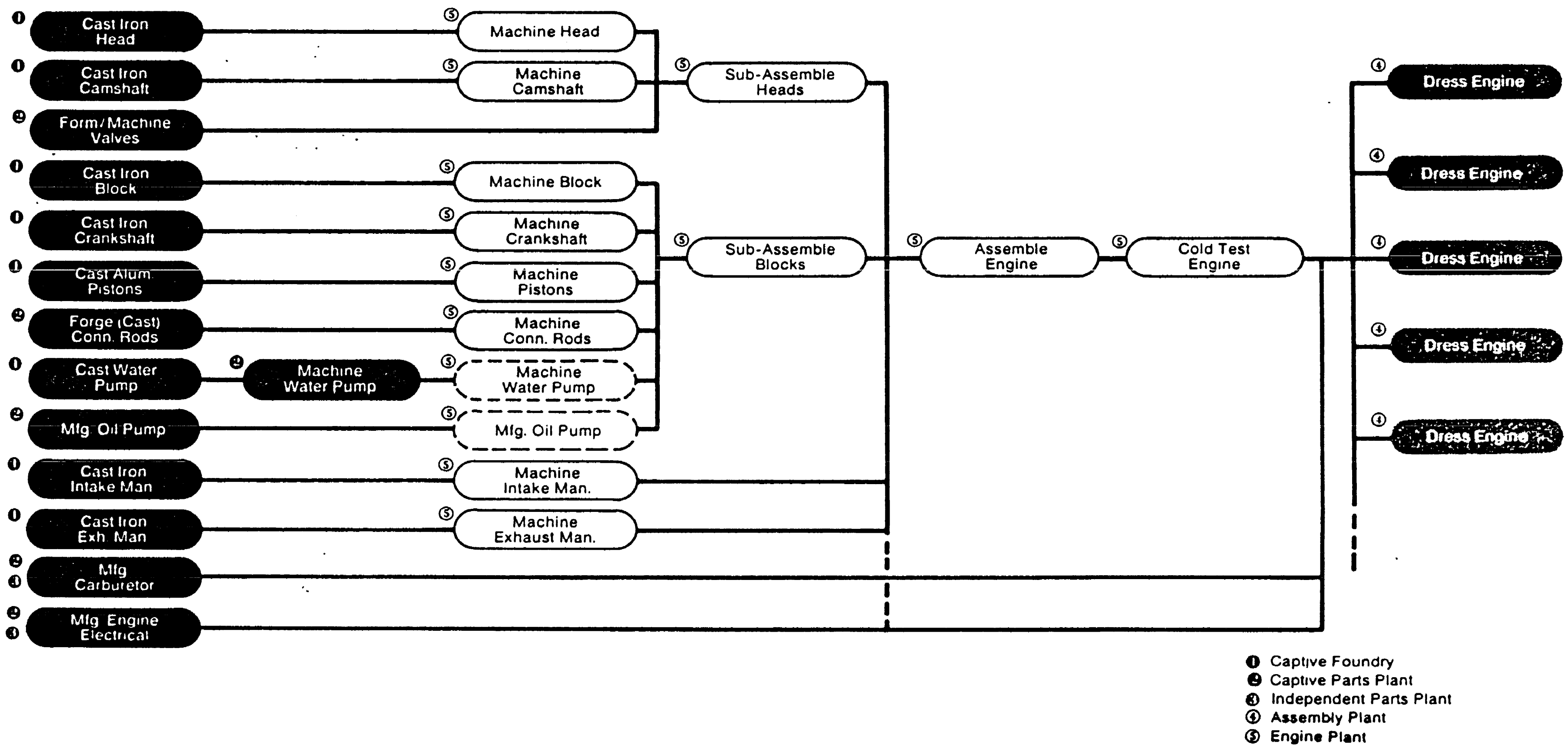


Exhibit 6

Current Typical Engine Build (mid-1980's)

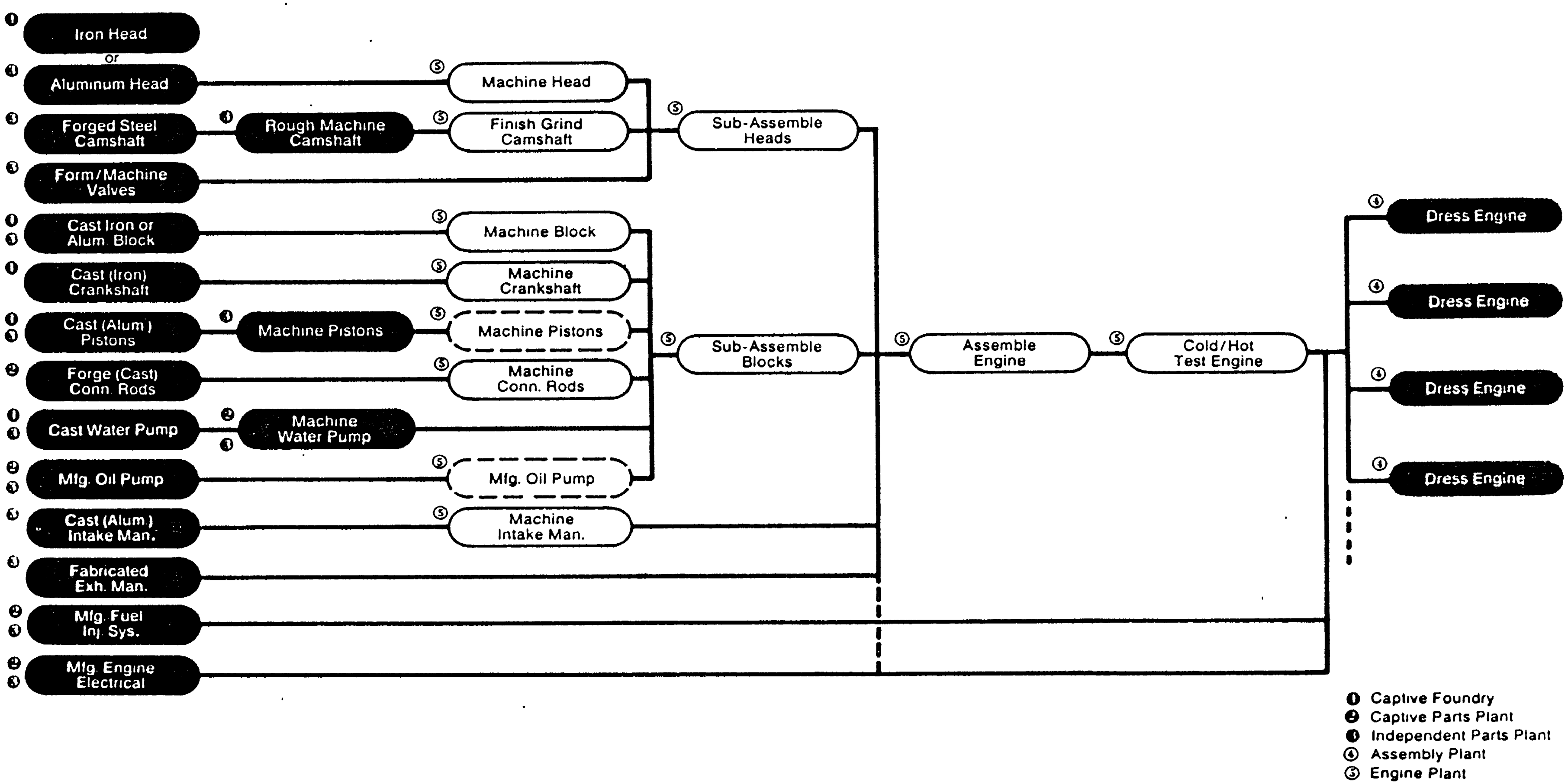


Exhibit 7

Possible Future Engine Build

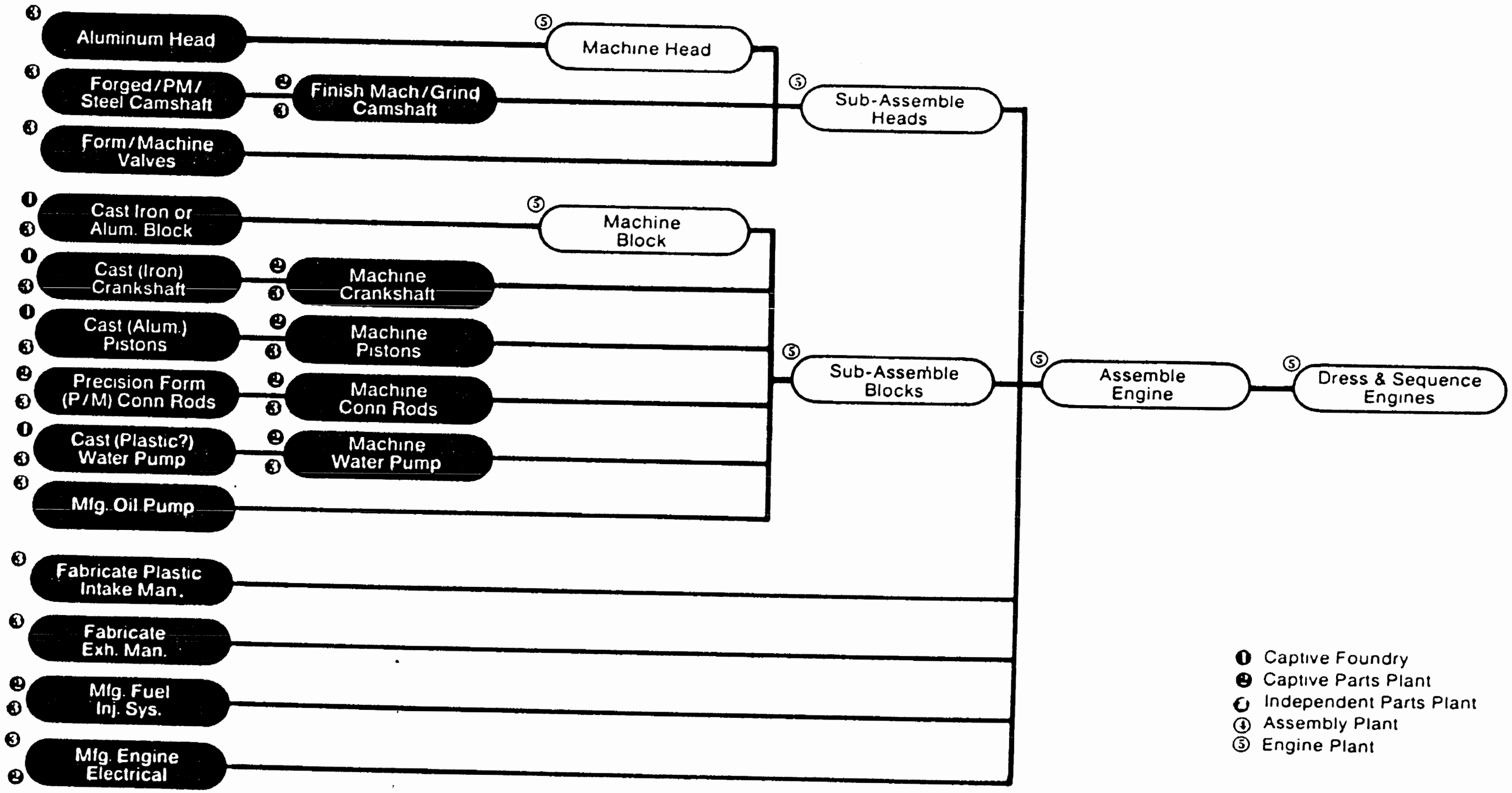
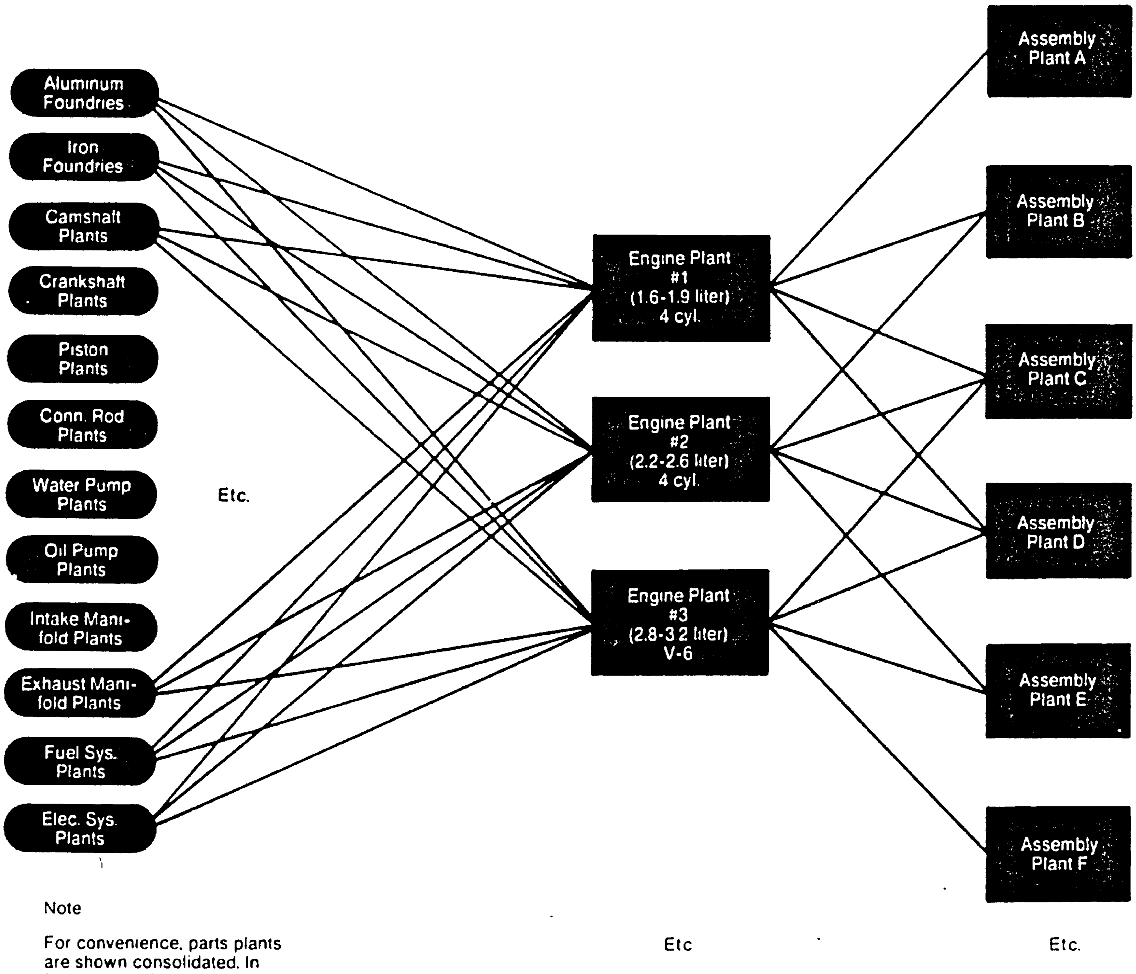


Exhibit 8

Focused Concentration Model

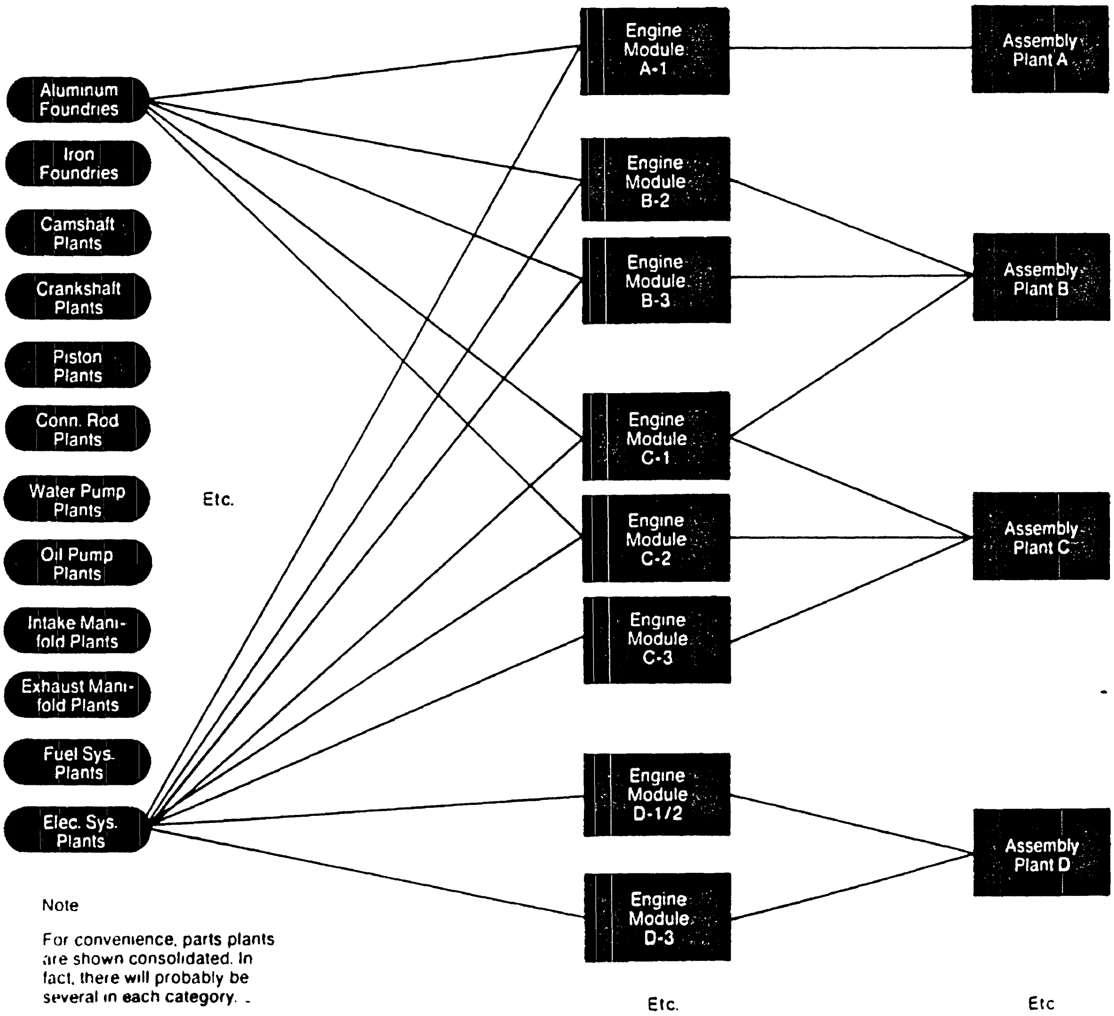


Note

For convenience, parts plants are shown consolidated. In fact, there will probably be several in each category

Exhibit 9

Contiguous Manufacturing Model



Note

For convenience, parts plants are shown consolidated. In fact, there will probably be several in each category.

Introducing AIM Research on Casting

The automotive casting industry is going through an accelerating capacity rationalization process. As the Big Three seek ways to reduce non-essential vertical integration, their captive foundries are at particular risk via a vis independent specialists. Since 1980, Ford closed a regional casting plant in Flat Rock, MI and has announced plans to close its Canton, OH forge by 1990. GM has closed its Central Foundry Division's Tonawanda, NY casting plant, is in the process of phasing out its Pontiac, MI foundry, and has announced foundry closings in Saginaw, MI (grey iron plant) and Massena, NY.

Recognizing their foundries' lack of competitiveness, several modernization/efficiency-improving projects are in process; GM alone is putting $200 million into the surviving CFD plants in Saginaw.

Is Upgrading Enough?

The upgrading of facilities may not, however, address a fundamental problem: because the Big Three have typically designed their castings with little input from the engine or transmission designer, they have generally turned out thick-wall, heavy, imprecise castings easy for the foundry to make but not optimal for the end product. Production quality practices also often reflected this "black art" caster mentality. As non-Big Three casters -- many of them offshore -- have successfully become significant suppliers to the automakers, radical technology and strategy shifts are now being contemplated. One route available is to close many, even most, of the captive facilities by (i) buying castings outside, (ii) substituting other processes for casting where feasible, (iii) substituting materials such as aluminum or magnesium for the traditional grey iron, and/or (iv) developing drastically new methods for casting.[1]

Our work will focus on the prospects for the fourth route: new casting processes, and particularly the evaporative casting technology in both iron and aluminum. Our initial findings suggest that a unique "window of opportunity" may exist to make a quantum leap forward in the casting business; such a leap would mean a great deal to Michigan, with its heavy foundry endowment.

In the near-term, however, more outsourcing of castings appears inevitable, particularly by GM as it strives to eliminate "non-core" operations.[2] In the past year or so alone, GM has outsourced blocks for its Quad Four engine to John Deere and announced that Teksid (a division of Fiat) will supply aluminum heads for its high-volume 60-degree V6s and 2.0-L 4. The 1990-92 Manhattan, 3200, and Saturn engines are all planned with aluminum heads and cylinder blocks, none of which GM now makes.[3]

---

[1]The major processes used for automotive casting include:

- Sand casting - used with iron and aluminum
- Semi-permanent mold - used with aluminum
- Diecasting - used with aluminum, magnesium, and zinc
- Evaporative casting (lost foam) - used with iron and aluminum

The major automotive applications of castings include:

Engines	Transmissions/Transaxles
Cylinder blocks	Cases
Cylinder heads	Case covers
Manifolds	Extensions
Oil pumps	Channel plates
Water pumps	

With the exception of the exhaust manifolds, all of the major castings can be produced in aluminum and by alternative processes to the traditional sand casting method. The cast-and-machined exhaust manifold has been largely replaced by the composite sheet metal manifold.

[2]One proof that outsourcing is not inevitable came with Ford's announcement that it would *reduce* aluminum cylinder head outsourcing beginning in 1987 by applying new technology in its Essex, Ontario captive foundry.

[3]GM *does* cast the aluminum block for the Cadillac 4.1L V8, but is far from "deep" in this line of business.

Evaporative Casting to the Rescue?

The retrofitting of grey iron casting plants to allow the pouring of aluminum is, we fear, unlikely. The accelerated development of the evaporative casting process for iron appears to be the most plausible (though perhaps still a long shot) way to save existing grey iron casting operations in the state. If its apparent promise proves out, it may also be a processing appraoch that pays dividends for the state's aluminum casters as well.

The evaporative casting process (ECP), or "lost foam," offers design flexibility, reduced machining, and other economies compared to traditional casting approaches. It uses polystyrene foam beads to make an exact duplicate of the part (the pattern), which is then coated with a refractory material and surrounded by loose sand. The container is vibrated to pack the sand around the pattern, creating a mold. Molten metal vaprozes the foam pattern, and as the vapor diffuses through the sand, the casting precisely duplicates the pattern's geometry, right down to tiny holes and channels.

The viability of the technology has been demonstrated in a number of materials, but it is not yet fully commercial in high-volume automotive applications for complex parts such as cylinder heads and differential cases. If lost foam is to take hold and make a difference, several things have to happen, among them:

- improved systems for reliable polystyrene pattern-making
- thorough process control methodologies for high volumes
- better understanding of certain key interactions:
    - between molten metal and foam
    - between pattern and sand during vibration
- more skilled casting plant blue- and white-collar staffs

Perhaps most important, the change to a radically new casting approach permits what may well be the most important cost-saving possibility: the optimization of product designs to take full advantage of a casting technology that can turn out *appropriately designed* parts close to their final shape, radially reducing machining time.

Can ECP turn Michigan casting around? If the process were already fully-refined in volume production around the world, it would probably be too late for Michigan for gain much from an adoption push. The early evidence we gave gathered indicates that most potential competitors are still at the stage of pilot line production and laboratory experimentation; thus there may still be time to act profitably.

TRENDS IN AUTOMOTIVE POWERTRAIN TECHNOLOGY

David E. Cole

In AIM I, significant changes in vehicle technology were explored to determine factors that could impact the Michigan Automotive endowment. It was plainly evident in our research that the powertrain (engine, transmission, final drive) was expected to undergo massive change in the next decade. In addition to the continued trends to front drive (with requisite shift to trans-axles) there is a rapidly accelerating pace of engine redesign. Based on individual interviews and preliminary data from the forthcoming forecast of industry trends, Delphi IV, fully 80% of the engines are expected to be redesigned and most built on new manufacturing hardware in the next ten years. In fact, only 30-40% of the existing manufacturing equipment is forecast to be used in the new engine facilities.

In AIM II we continued to examine the impact of change in the powertrain, particularly as affected by basic engine redesign and advances in electronic technology. Clearly, with any change of the magnitude forecast in basic engine design and the continued application of advanced electronic components, there is the potential for major changes in the components and sub-systems leading to significant dislocations in the supply base.

ENGINE COMPONENT COST BREAKDOWN

Valuable insight was provided on the new wave of "teched" engine by one manufacturer that is presently preparing an advanced and totally redesigned engine for production. Key features include aluminum head with double overhead cams, four valves per cylinder, fabricated stainless steel exhaust manifold, direct fire distributorless ignition, and multi-port electronic fuel injection. Based on the design specifications and preliminary data this engine is clearly world class. It is, however, probably not a future "average" engine, but rather one intended for up market specialty vehicle applications. The extent of market penetration of this engine type will be dependent on market forces. A relative cost component breakdown is shown in Table 1 for this engine compared to similar data for a vintage design V-8 engine of approximately 1975.

TABLE 1

Relative Cost Estimate of a 350 Cubic Inch V-8
& 2.3 liter 4 cylinder, 4 valve Pen Chamber

Subsystem	V8-350 W/2BBL % of Installed Cost	L4-2.3L W/MPFI % of Installed Cost
Cylinder Block	15	6
Cylinder Head	9	4
Crank Shaft & Balancer	6	3
Fly Wheel	1	1
Piston Assembly	10	4
Oil Pan	1	2
Oil Pump & Lub. System	1	3
Fan & Drive	3	2
Water Pump, Drive & Hoses	2	3
Manifolds	6	13
Carburetor - Fuel System	4	10
Air Cleaner	2	1
Fuel Pump	1	- (Incl. in Fuel Sys.)
Engine Mountings	2	3
Camshaft & Valve Train	8	13
Rocker Arms, Shafts, Covers	1	4
Generator & Regulator	7	4
Starting Motor	5	3
Distributor	3	6
Spark Plugs, Wire, Coil, Switch	2	- (Incl. with Dist.)
Miscellaneous	1	5
Assembly Effort	10	11
	100%	100%

In general, the new engine represents a considerable increase in value added per cylinder, as well as for the total engine compared to the V-8 design. While individual unit cost data is proprietary, a reasonable base cost for the high-tech four might be $1,000. Major new supply opportunities are evident throughout the base engine and in the electronics (certainly compared to the 1975 design). Fabricated manifolds, aluminum castings, fuel injection components and an additional camshaft are key examples of new opportunities. Of course, significant reductions are also evident: much lower mass of cast iron in the block, head and manifolds, fewer pistons, and no carburetor. This clearly suggests that as changes occur, there will be both winners and losers from the supply base but potentially more winners because of the higher level of value added.

DELPHI IV

The 1986 forecast, Delphi IV, addresses a wide range of topics including powertrain and body and chassis technology, engineering materials and the future market. I must emphasize that the data presented are first round results of the Delphi process and are not necessarily the consensus that will be reached after the final round. Furthermore, the results shown are the average of the median forecasts for two separate panels, powertrain and body/chassis. Both panels were asked common questions on electrical/electronic issues.

Macro Engine Trends -- Based on preliminary Delphi IV results, it is evident that important changes are forecast in engines. The enormous level of basic change in the overall engine was noted earlier. Clearly with a change of this magnitude the traditional supply base is vulnerable unless it can meet the technological and manufacturing precision challenges in addition to their customers demands for world class quality and price.

Engine Materials -- An accelerating use of aluminum in heads and blocks is forecast. By 1990, 35% of heads and 10% of blocks are expected to be made from aluminum. These percentages expand to 60% for heads and 20% for blocks by 1995. Most aluminum cylinder heads will use cast iron sleeve inserts, but some aluminum "bare bores" will be used. Overall, many materials changes are forecast throughout with a far greater role for both plastics and aluminum. The following qualitative forecasts are for 1995:

- Crankshafts -- predominant cast iron but growing percentage of steel

- Camshaft -- Powdered metal is expected to come on strong and compete with both steel and iron designs

- Piston -- Aluminum will dominate but improved materials and processes are expected e.g., aluminum with fibre reinforcement. Squeeze casting and forging are the primary processes suggested. Ceramics are expected in a small fraction of piston crowns as are plastic skirts.

- Connecting Rod -- Approximately equal fractions of steel, cast iron, powdered metal and composite materials are forecast.

- Intake manifold -- Fully half of future intake manifolds are expected to be made from plastic (predominantly injection molded), a third from aluminum and the remainder from iron and steel.

- Exhaust manifold -- Approximately two thirds of 1995 exhaust manifolds will be fabricated from steels, both coated and stainless. Stamped and welded tube construction will dominate. Most of the remainder will be cast iron. Ceramic coatings will be used on some manifolds to enhance heat conservation and protect the metal.

- Oil Pan -- Here also plastics are expected to dominate (two thirds) with the remainder split almost equally between steel and aluminum.

The massive materials change suggest a potential significant discontinuity in the supplier base. Detailed developments must be watched closely.

Engine Configuration -- Compared to Delphi III there is generally a modest upsizing and cylinder number increase evident in Delphi IV. Table 2 shows the breakdown of engine cylinder number forecast for 1990 and 1995.

TABLE 2

Passenger Car Engine Cylinder Number

Cylinders	1985	1990	1995
3	0%	0%	2%
4	47	49	50
6	26	30	35
8	27	20	11

Engine displacement trends are shown in Table 3. Clearly the midsize engines, 2-4 liters, will dominate.

TABLE 3

Passenger Car Engine Displacement

Displacement Range (liters)	1990	1995
5.0 +	5%	2%
4.0 - 5.0	10	10
3.0 - 4.0	25	25
2.0 - 3.0	30	32
1.5 - 2.0	18	20
Below 1.5	3	5

Diesel engines will play a very minor role in passenger cars (2% for 1990) and a modestly greater role in light trucks (10% for 1990). No alternatives to either the diesel or gasoline are forecast in any significant quantities by 1995.

Engine Features -- Numerous changes are anticipated in a host of engine features that could impact the supplier base. In some cases, existing components will be replaced and in others significant value added. Forecasts for a number of engine feature changes are shown in Table 4 for 1990 and 1995.

TABLE 4

Forecast of Passenger Car Engine Features

Engine Feature	1990	1995
Multi Point Fuel Injection	30%	50%
Single Point Fuel Injection	50	40
4 valve Combustion Chambers	10	25
3 valve Combustion Chambers	5	10
Dual Overhead Cam	10	20
Roller Valve Lifters	40	50
Hollow Cam Shaft	5	20
Distributorless Ignition	20	50
Balance Shaft (% 4 cyl.)	20	20
Knock Limiting Device	50	60
Turbocharger	10	12

Transmission/Drivetrain Trends -- The drivetrain, including the transmission, will continue to undergo change in the decade ahead. The rate ofincrease in front engine/front drive configuration will moderate as the major fraction of future vehicle are converted to this technology. By 1990, 70% of passenger cars are expected to use front drive with a modest expansion to 75% by 1995.

The transmission forecast for 1990 and 1995 is shown in Table 5.

TABLE 5

Forecast of Transmission Type

Transmission	1990	1995
Manual - 4 speed	10%	5%
Manual - 5 speed	20	25
Automatic - 3 speed	30	15
Automatic - 4 speed	40	45
Continuously Variable (CVT)	1	5

The split between automatic and manual designs is similar to the forecast in Delphi III. However, the expectations for the CVT are greatly diminished because of serious manufacturing problems being encountered with the segmented belt. With resolution of this problem, the role for the CVT could expand significantly.

Problems with present automatic transmissions were explored with the Delphi panel. Poor shift quality, durability and reliability headed the list of concerns and suggests rather strongly that significant quality improvements are necessary.

Vehicle Features -- A number of new vehicle features will begin appearing in an increasing fraction of U.S. light-duty vehicles in the next few years, particularly in the low volume, specialty segment. In most instances the potential of these features is heavily dependent on electronic technology. Table 6 shows a number of features and their expected market penetration in U.S. produced passenger cars by 1995.

Table 6

Forecast of Feature Content in 1995 U.S. Passenger Cars

	1995
Anti-lock brakes	50%
Driver controlled ride/handling mode	25
Active suspensions	20
Air bags/passive restraints	20
Four wheel drive	15
Active four wheel steering	10

Clearly if this forecast materializes, it will mean a major increase in the content of advanced technology componentry.

Electronic Trends -- The fraction of total vehicle cost represented by electronics for an American produced passenger car is expected to be 12% by 1990 and will be approximately 17% by 1995. This forecast represents a modest increase in expectations compared to Delphi III. Based on a typical mid-size passenger car of $10,000 cost, this suggests that by 1990 approximately $1200 of cost will be in electronic components; transducers, actuators, microprocessors, and the like. By 1995 this value should expand to $1700. These increases for electronic componentry are not surprising considering that electronic vehicle functions will increase dramatically (anti-lock braking, electronic fuel injection...) in the next ten years. However, these significant percentages are quite surprising when one considers that reduced unit costs, component integration, multiplexing, expanded memories, improved design procedures, more efficient software and intense cost competition all could push in the direction of lower unit costs for electronic components.

We envision a future market character that will be very different from the past, which was more or less a single continuum from small to large cars. Today at least two distinct segments are emerging: a lower technology, high volume or commodity segment; and a higher technology, low volume, specialty segment.

When the electronic cost breakdown is extended to these primary segments of vehicles it is clear that the impact is indeed dramatic -- particularly for upper scale products. In lower technology vehicles the electronic fraction of total cost is forecast at 8% for 1990, whereas the fraction of cost in higher technology vehicles may be as much as 16%. By 1995 the cost fraction is forecast to grow to 11% and 23% respectively for these vehicle segments.

New Electronic/Electric Applications -- A host of new electrical/electronic applications are expected to reach commercialization (defined as 30,000 units per year production volume) by 1990 in U.S. vehicles. Some of these were considered as vehicle features in Table 6. Applications include:

- Electric/Electronic Power Steering
- Anti-lock braking
- Electronic transmission control
- Sophisticated body/engine diagnostics
- Multiplexing

- Electronic suspension control
- Traction control
- Advanced sensors
- Advanced navigation/information systems
- Increasingly integrated controls/components

By 1995 increased market penetration of the features on the foregoing list is forecast along with the addition of new features including:

- Heads-up displays
- Fiber optics in controls
- Drive by wire/electronic throttle
- Cylinder pressure sensors

- Voice recognition systems
- Power adjusted convenience controls
- Radar braking, collision avoidance
- Smart power switching

Numerous other electronic features were expected to attain commercialization by a relatively few panelists. Features suggested ranged from various entertainment and business options to low tire pressure warning devices and variable valve timing. It must be noted that with the reach or vision of this study there is considerable chance for error and the possibility that a minority of the panelists really do have the best vision of the future. Thus, advances receiving even little attention by the majority of panelists may indeed be the "bombshells" ten years down the automotive road.

It appears that integration of electronic components will occur at a steady pace during the next ten years leading to a more simplified and reliable system. Many of these features are either directly or indirectly associated with the powertrain.

Electronic Component Cost Projections -- A significant fraction of the various vehicle subsystem cost is forecast to be in electronic componentry.

The forecast breakdown by sub-system is shown in Table 7.

Table 7

Forecast Electronic Cost as Percentage of Subsystem Cost

	1990	1995
Engine/Transmission	10%	15%
Comfort, convenience, entertainment	40	50
Chassis, suspension	5	12
Safety	4	10

Diagnostics -- An important growth area for electronics is evident in the trend to a more comprehensive vehicle diagnostic capability. This applies both to electronic features themselves as well as a host of electro/mechanical/hydraulic components or subsystems.

By 1990 panelists expressed particularly strong support for advanced diagnostic capabilities in the engine, transmission and climate control areas. Other areas or components receiving mention for diagnostics were:

- Braking systems
- Body electrical and lighting
- Emissions (could be included with engines)
- Steering
- Tire status
- Fluid levels

In the 1995 forecast, special emphasis on the basic functions of various service items and accessories (fluid level, chassis service, wipers, cruise control, charging,...) was evident. In addition, suspensions will be included as more electronics are applied to this area in anti-lock braking, four wheel steering, and active ride control.

Multiplexing -- One of the most interesting technical areas in light duty vehicles is the future role of multiplexing. Clearly it is an emerging technology and has already reached commercialization in some specialized vehicles and component areas. By 1990, 4% of U.S. produced passenger cars are expected to use multiplexing and this is expected to expand rapidly to 23% by 1995.

A number of areas were suggested for the application of multiplexing with the door interface (power seat, window, mirror controls...), steering column, lighting controls, and entertainment system being mentioned most frequently. It is evident that wiring harness size and complexity (prompted by the growing demand for functions) is creating a significant burden in a number of areas with tough packaging constraints. Furthermore, cost and quality issues are also driving the technology forward. Other areas where multiplexing appears attractive include vehicle information/instrument panels, climate controls and other body wiring. Engine related areas received modest multiplexing support.

It should be noted that most panelists are systems oriented and detailed application of advanced technologies such as multiplexing may be immersed in various subsystems and essentially invisible. This is another reason that in evaluating forecasts of this type, individual comments and items receiving only modest support from panelists should be considered seriously.

There is considerable uncertainty as to the ultimate architecture of multiplexed systems and, indeed, several concepts may mutually coexist. Electrical signal distribution with smart power switches was the preferred technology, although fiber optic signal transmission is expected to be increasingly important in the view of a number of respondents. Still, there is great uncertainty and this view is supported by comments such as "The jury is still out", and "...a function of time: eventually fiber optics will predominate but I don't know how soon."

ELECTRICAL/ELECTRONIC IMPACT ON OVERALL VEHICLE

Few technological areas represented in the modern vehicle have had, and will continue to have, as much impact as electrical/electronic advances on the product and the industry. Clearly the ability of modern engines to meet vigorous federal fuel economy and exhaust emission standards while still providing a driveable vehicle is largely due to advanced electronic control systems.

While attention has generally been directed at electronic components such as transducers or sensors, actuators, and microprocessors, a revolution is mounting in traditional electrical components such as the ignition system, motors, and wiring. (We will hereafter refer to the combined electrical/electronic part of the vehicle as E/E.)

It is important to recognize that E/E components can not always be viewed as replacements for mechanical components. In many instances, new functions can be added because of E/E and in turn spawn demand for new mechanical components. It must be kept clearly in mind that E/E components are not an end unto themselves in most vehicle systems but are only a part of the control strategy in which they generally function better than mechanical or hydraulic control elements. Ultimately, processed and managed information derived from mechanical/hydraulic/thermal ... systems through sensors must be fed back to these same systems with actuation devices. The basic mechanical components survive and only the archaic and inadequate elements (compared to E/E components) are eliminated.

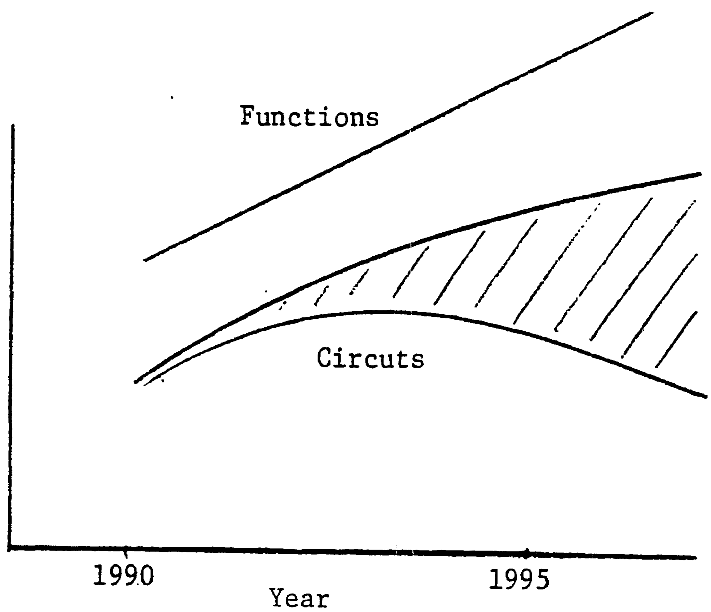
Key factors driving the E/E revolution include:

- New Functions
- Quality/Reliability
- Cost
- Packaging
- Diagnostics
- Regulation (e.g. CAFE, emissions)

Important changes within E/E components are quickly moving this technology to an ever increasing level of sophistication. Key advances include:

- Lower cost, more powerful microprocessors with greater memory
- Component integration/rationalization-bring distributed components together in a systematic manner
- New permanent magnet and other materials advances - reduced size, weight, and cost of motors, solenoids and other actuators
- Multiplexing - permits reduction of wiring harness complexity and improves packaging
- Modular wiring - aids modular assembly procedures
- More rugged, inexpensive and reliable sensors, actuators, and other components
- Advanced software and system design capabilities - we are learning to engineer electro/mechanical systems properly
- Advanced diagnostic capabilities

Functions dependent on electronics are expected to increase rapidly (ABS, electronic fuel injection, E/E powersteering, trip computers...), but with advances such as multiplexing, component integration, expanded memories, and improved design procedures. Simplicity could once again return to the vehicle although there is considerable disagreement among experts on this issue. The following figure shows expected qualitative trends. Number of circuits (wires and connectors can be used to denote



system complexity. Model year is plotted on the abscissa. Note that there appears to be considerable uncertainty and disagreement among experts with regard to system simplification. The technology is moving too rapidly to permit precise quantitative projections. Furthermore, in an increasingly market driven business the consumer will play a profound role in determining the winners and losers in new functions. It is clear that both manufacturers and suppliers will need to move from an add-on option mentality to a systems integration approach when viewing electronics. The development of any electronic based feature must first recognize the overall system parameters.

PERSONAL INTERVIEWS -- ELECTRICAL/ELECTRONIC AND PRODUCT CHANGE IMPACT

A series of personal interviews were conducted with more than twelve representatives of the three major domestic manufacturers to assess the impact of electrical and electronic technology and product change on vehicle systems. Most of these focused on the powertrain. However, one set was directed at the chassis and suspension area. This section will be divided into three parts: engine, transmission, and body/chassis.

Engine

As noted earlier, dramatic change in the overall automotive powerplant are forecast and the individual interviewees concurred. It is important to note that the engine was the first major system impacted by E/E with the introduction of electronic controls and ignition components during the past ten years. This was prompted by the extremely difficult challenge of meeting combined requirements for fuel economy, exhaust emissions, and driveability. Considerable refinements have been made to the initial E/E components.

The impact on traditional engine hardware has been dramatic in areas such as the ignition system where the breaker points (and associated components) and spark control devices have essentially disappeared. In the fuel management system, the traditional carburetor is fading fast giving way to either the single-point or multi-point fuel injection system.

It is critical to understand some of the basic similarities and differences between the U.S. and Japanese engine strategy to date. The Japanese, for example, chose to meet rigid emission and fuel economy requirements in their smaller cars by producing lightweight, highly engineered, low friction components built with a high degree of precision. Generally, this strategy resulted in more expensive engine hardware but achieved an acceptable level of emission control and excellent fuel economy with a minimum of electronic control. Consequently, the Japanese did not have to develop as sophisticated controls as the U.S. manufacturers. Their cost savings in E/E components more than offset the added engine cost yielding a net advantage. In the U.S. we made up for hardware deficiencies with electronic control which resulted in a net cost deficiency. With the current re-design of U.S. engines, we are learning to take better advantage of more precisely designed and manufactured components and sub-systems, and in turn, incorporating advances in control technology which are today becoming highly refined. This should yield outstanding future powerplants. However, there is a possibility that some of the control may not be needed, as the Japanese discovered. With the possible tightening of emission standards for NOx and hydro-carbons, the challenge of meeting the emissions, fuel economy, driveability and cost trade-off will return and require very advanced E/E control together with the new engines.

With some component exceptions, most engine systems and sub-systems will not be replaced with continued application of automotive electronic devices in the next five to ten years. The basic thermal mechanical aspects of the engine will remain intact with pistons, crankshaft, valvetrain, heads, block, etc. Of course, significant changes will occur in all components with re-design.

Change will increase the potential for new business opportunities for many and threats to some. The supply base, in total, should be a net winner because of greater value added. It is clear that future component suppliers must be technically advanced and capable of building world class parts at world class prices. This indeed is a major threat to the traditional Michigan supplier base. In some areas already, for example in pistons, early sourcing for new engines has focused extensively on foreign manufacturers.

Engine, E/E Impact -- A series of key points were raised in the interviews.

- Quality is a driving force in every decision today. It must be assured with any component, mechanical or E/E.

- Near term the basic engine components will functionally be the same with little direct impact by E/E components. Exceptions include fuel and ignition system components that will be eliminated by the switch to distributorless ignition and electronic fuel injection.

  Longer term the desire for variable valve timing may lead to different valve actuation perhaps electro-mechanical but the transition is beyond the scope of the current AIM project.

- Emphasis on integration of engine and transmission controls with total electronic management. The transmission part is the weak link. In the engine essentially all mechanical control elements (e.g. vacuum and centrifigal spark advance mechanisms will disappear).

- Failure modes and reliability concerns limit electronic application to date. This will improve rapidly with reduced system complexity and advanced component design including redundency. Reliability is absolutely a critical issue.

- Drive by wire (electronic throttle) could appear in the 1990's. Several key components would probably be eliminated:

    1. Cruise control assembly
    2. Throttle linkages
    3. Some emission controls, possibly EGR.

- Changes in sensors and actuators are likely with electronic logic (smarts) at the device. Present day units are vulnerable. Good and inexpensive mass air flow, torque, position and cylinder pressure transducers are needed.

- Emission control system could be simplified (depending on trends in regulation) with combination of new engines and advanced E/E control. EGR valves, air pumps and air injection manifold and other assorted plumbing is vulnerable.

- Stronger enforcement of "in use" emission performance should focus attention on system reliability. Component durability and simplicity could be emphasized.

- In system where EGR is required much more durable units are needed.

- In ignition systems there is a possibility that coils will be replaced with high voltage diodes.

- Gallium arsinide chips could appear in underhood area because of temperature tolerance therefore putting "squeeze" on silicon chip materials.

- Multiplexing is not likely to be a strong factor in the powertrain.

- Cost benefit analysis may still favor basic mechanical systems in some areas. At this point we can not assume the E/E will do everything but the trend is definitely to E/E with software replacing hardware.

- Speedometer cables highly vulnerable to electronics.

- Pulse width modulation in actuators of many types looks strong.

- Manufacturers are looking for big partners, small suppliers will work at lower levels in the supply chain unless they can offer special technology.

Transmissions

Automatic transmissions are unlikely to undergo the degree of change expected for engines. Of course some change in mix will be evident as more 5-speed manual designs replace 4-speeds. Furthermore, the continuing move to front drive vehicles will spawn more front transaxles and fewer rear drive transmissions. The major changes being addressed by automatic transmission suppliers can be considered in a four step sequence:

1. Improve the quality and torque/power capacity of existing designs. This process is being pursued aggressively by all manufacturers. Quality refers to a range of factors including shift feel, freedom from fluid leaks to reliability and durability. Most of the changes in this step are associated with refinements in existing technology. Fundamental redesign is generally not required. Obviously existing suppliers will be required to improve component quality. Those that are not able to meet the appropriate performance objective at a reasonable cost are indeed vulnerable.

2. Electronic transmission controls are likely to begin appearing in some U.S. automatic transmissions in the next several years but the "teching" process is likely to be reasonably gradual. Of course today, lock up torque converters generally utilize electronic control already. Initially the basic hydraulic control elements will be replaced with electronic components although actuation will probably remain hydraulic for some time. Transmission control components such as valves, valve bodies, accumulator, governor, vacuum lines and springs, etc. will be replaced. The basic transmission elements designed to handle drivetrain torques and forces will remain largely intact. Despite the fact that electronics appear to be coming quickly, there is growing concern that the cost/benefit aspects may not be favorable and the progress could be sidetracked until these concerns are alleviated. Of course, electronics are favorable for integration of the engine and transmission control strategy.

3. Elimination of hydraulic actuation valves is the final step with automatic transmissions of current basic design. By no means were our panelists convinced that this transition is imminent. In fact cost/benefit concerns are significant and considerable invention and innovation are needed. In addition, there are real concerns with failure modes.

4. The Continuously Variable Transmission (CVT) could begin to appear in a very limiteed number of small vehicles by 1990. As technological and production problems are resolved, the CVT could aggressively displace conventional automatic transmissions but not until well into the 1990's. When and if the CVT appears it could have profound impact on the transmission supply base.

Transmission changes are likely to move forward more slowly and orderly than in engines. Consequently, the supply base is probably going to be able to address change without serious dislocation unless of course cost and quality barriers occur. However, with the shift to electronic transmissions, new supply opportunities will develop including demand for:

- force motors, solenoids
- torque sensors
- positioning devices
- various electro/mechanical/hydraulic devices

Body/Chassis

One interview was conducted with 4 representatives of one vehicle manufacturers advanced electronic group to assess the impact of electronics on the body/chassis system. There was general agreement that electronics are moving quickly in a number of subsystems. With several notable exceptions, electronics will generally add value in body/chassis systems.

Anti-lock brakes are expected to experience rapid growth. Electronics are fundamentally involved. Most existing components with the possible exception of the master cylinder will continue to be needed. Considerable overall value added is envisioned.

Four wheel drive is likely to be used in a reasonable fraction of specialty vehicles. Electronics will play a modest role and overall value added will increase considerably.

Electric/electronic power steering is expected to replace current hydro mechanical types. Features include smaller package requirements and fuel savings of about 1/2 mpg. Significant dislocations will occur in present designs with the elimination of the pump, tubing, drive pulley, belt, etc.

Active suspensions and steering are undergoing active research and development programs. Significant benefits are available with active ride and handling control and active four wheel steering although the cost at this point is projected to be substantial. Significant use is only expected beyond 1990 with primary applications in specialty vehicles. In general these systems will add considerable value with a minimum displacement of existing components. Greater flexibility in designing and tuning vehicles is envisioned with these systems. Serious concerns remain with regard to failure modes.

Advances in both powertrain and body/chassis areas are expected to lead to a more highly integrated total vehicle control strategy. Advanced electronics are key to achieving this goal.

SUMMARY - Component "Watch List"

The potential for significant dislocations exist in light duty vehicle powertrains due to the application of electronics and system redesign. However, the basic mechanical components in current and mid-term future powertrains will remain functionally the same and a considerable increase in value added is likely. Following is a "Watch List" of components vulnerable to change:

- Any component or subsystem not matching world class price and quality criteria
- Distributor based ignition system
- Carburetors
- Control linkages and cruise control - longer term with electronic throttle control
- Emission control components - EGR valve, air injection pump and manifolding
- Speedometer cable
- Substantial fraction of current E/E components
- Automatic transmission hydraulic control components - valves, valve bodies, springs,....
- Hydromechanical power steering system

AIM NEWSLETTER

The Auto in Michigan Project

A State of Michigan Program with the Office for the Study of Automotive Transportation University of Michigan

Volume 1, Number 1 **December 1985**

For the past year, a unique endeavor has been sponsored by State government. The Auto-in-Michigan (AIM) Project, a team of researchers and policy leaders, has been at work seeking to understand the forces affecting the state's leading industry and, based on that understanding, to suggest State government actions to prepare for likely developments in the 1986-1992 period.

This, the first issue of the Project's newsletter, summarizes the 300-page 1985 Report of the AIM Project. It presents, in capsule form, our major findings and conclusions so far.

During the past year, we have moved within an industry that is making an impressive effort to transform the ways it mobilizes resources to compete in the international marketplace. In Detroit and Grand Rapids, in Flint and Sterling Heights, and in Lansing we have seen leaders moving an industry forward. During the rest of this decade and well into the next, however, Michigan's auto industry leadership must navigate heavy seas. Continuing turbulence thus remains the only realistic forecast for auto in Michigan.

Most of Michigan's nineteen car and light truck assembly plants now or soon will host new or nearly new vehicle programs. A few big plants are at peril, however, and more will be as our now-unrestrained Japanese competitors claim a larger share of the U.S. market.

We have observed a fundamental change in auto makers' relations with suppliers, a process that will surely reduce the number of Michigan firms with which they directly conduct business.

The application of computer technology to the design, engineering, prototyping, production, testing, and marketing of the automotive product will increase rapidly during 1986-1992. The transformation, driven by digital technology, will be disruptive, but it can yield substantial benefits for Michigan if new efficiencies reduce costs and defend U.S. market share, and if Michigan grows as a center of initiative in computer-integrated manufacturing.

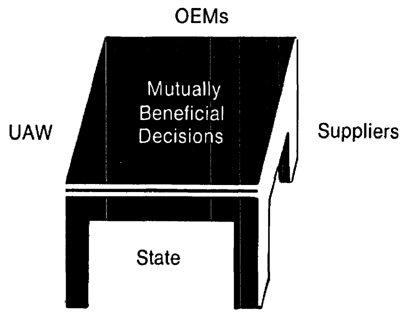
The cars of tomorrow will contain more aluminum and engineering plastics, bringing both risks and opportunities for our state. Iron foundries dedicated to engine and drivetrain components may face difficult times as aluminum casters and smelters that serve them claim new automotive business in engine blocks, cylinder heads, intake manifolds, transmission cases, and lesser components. Plastics will challenge stamped steel as the "skin" of choice in a widening range of U.S.-produced vehicles. This crucial contest should be watched with care in Michigan, for whatever its resolution, many jobs will be lost, and others created.

These findings, and the many others that follow, convince us of the need to strengthen the special bonds between government and the auto industry in Michigan. The AIM Project is an ambitious experiment in the education of government by industry. AIM is also a public effort to provide analysis of direct, practical value to the managers and owners and workers who are the most important stakeholders in Michigan's automotive economy.

We believe that a healthy automotive sector depends on informed dialogue among those stakeholders. Each has particular interests, but also some goals in common with the others. Think, if you will, of a four-sided table at which the state is joined by the auto makers, their suppliers, and the UAW. Imagine the parties discussing our findings, and seeking mutually satisfying courses of action to meet both the risks and the opportunities generated by the automotive industry as it changes in this state over the next six years. On the agenda:

- How can Michigan, as a high-wage, highly-unionized state, maximize the advantages of proximity to OEM assembly and regional component operations? Are there public sector actions not now being taken that could provide cost-effective incentives to greater clustering of supplier facilities? What can the State do to increase the extent to which first-tier suppliers of modular subassemblies build up their modules from discrete parts produced in the state?

- Are there cost-effective State actions that could provide constructive new uses for automotive facilities that become vacant? Is it possible for the State to work with private business and with labor to co-plan the future of such apparently at-risk facilities?



Siting of Vehicle Programs

The State's economic health depends on maintaining its share of vehicle assemblies. Action to replace the production that will be lost when current programs expire at Clark/Fleetwood, Pontiac Plant 8, Dearborn Assembly, Wayne Assembly, Jefferson Assembly, and Chevy Truck (Flint) is thus a high priority.

There is reason to expect that sharp increases in import share — already appearing in the wake of the non-extension of limits on Japanese cars — will make it extremely difficult for the state to maintain its current unit production, especially as Japanese competition begins extending further into the intermediate segment.

Six of Michigan's nineteen car and light truck assembly facilities are at risk in the 1986-1992 period. Three of these are endangered by the shift toward front wheel drive: GM's Clark/Fleetwood operation and its Pontiac Plant 8, and Ford's Dearborn Assembly Plant. All three are old, multistory structures; none has on-site dedicated major panel stamping capacity or a fully modern new-style paint shop. All produce rear wheel drive vehicles introduced more than a decade ago. A fourth at-risk assembly operation is Ford's Wayne car assembly line, due to increased small car imports.

We expect that two of these endangered plants will be the site of future new vehicle programs. Pontiac Plant 8 is the probable future home of the plastic-skinned 1990 GM80 Camaro/Firebird successor. Wayne Assembly, because of its quality record and workforce reputation, will likely be chosen for a future Ford car or light truck program even if, as we fear, there is no high domestic content successor to the Escort/Lynx line. That leaves Clark/Fleetwood and Dearborn Assembly. The former, though bolstered by the addition of remaining B-body volume in 1986, is likely to close in 1990 or 1991. Dearborn Assembly appears destined to close at about the same time, as Mach 1 (reskinned Mustang) production phases out. In both cases, action to find new uses is recommended.

Two other Michigan assembly plants are also at some risk: Chevy (Flint) Truck, already cut back from two lines to one, and Chrysler Jefferson, if the 1988 A-body successor to the K-body is sited elsewhere.

There is also the issue of foreign direct assembly investments. While the U.S. and Michigan gain when vehicles that otherwise would be shipped from abroad are instead assembled here, the typical Big Three Michigan assembly plant generates two to six times as much Michigan manufacturing activity as the typical foreign-owned or joint venture assembly operation. This, of course, is due to the former's higher U.S. content (85-98% versus 25-50%) and its greater propensity to purchase major inputs from existing Michigan suppliers.

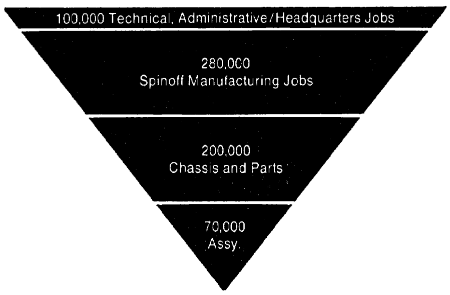
Risk Ratings of Selected Car and Light Truck Assembly Plants

Plant/Current (1985) Program		1986-92 Plant Risk Score
Clark/Fleetwood	B, D	27
Buick City	H	0
Flint Truck	C/K	10
Wayne (Car)	Erika	18
Dearborn	Fox	27
Jefferson	K, E, CV	11
Sterling Hts.	H	3
Warren (Dodge City)	D/W	7

Input Sourcing

Major sales and job losses loom for Michigan's frame, stamping and axle plants. New aluminum engines, and perhaps manual transaxles, present future business opportunities. Efforts need to be made to increase the Michigan content of vehicles made in new foreign-owned and joint venture U.S. assembly plants.

Michigan's approximately 70,000 jobs underpin 200,000 captive and independent supplier jobs and another 280,000 state manufacturing jobs, for a total of about 550,000. Adding jobs at corporate and divisional headquarters, technical centers, and proving grounds swells the figure to 650,000, or about 55% of Michigan manufacturing employment.

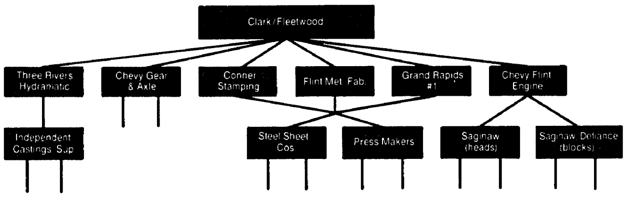


The phaseout of GM B-, D-, G-, and T-body cars will impact volumes at Chevy Flint Met Fab, Grand Rapids 1, Chevy Flint Engine, Chevy (Detroit) Gear and Axle, and Three Rivers Hydra-Matic. Termination of the Fox (Mustang/Capri) program would endanger output at Dearborn Stamping, at the Utica and Chesterfield trim plants, and (to a lesser extent) at Sterling Axle. Increased imports would hurt Michigan plants producing stampings, engines, and transmissions for GM J-body, Ford Escort/Lynx, and Chrysler Omni/Horizon models. Rising market penetration by low-U.S. content domestically-assembled cars will reduce traditional U.S. OEM part demand by at least 14%, and perhaps by as much as 34%, just between now and 1987. Increased vehicle outsourcing by the OEMs — some of it offshore — will reduce partsmakers' volumes still further, with significant costs to Michigan businesses.

In major frame stampings, the Ford Rouge Frame Plant is at risk unless additional truck frame work is added. The emerging trend, in GM at least, toward space frames (or "bird cages") may be an opportunity for Michigan producers, within and outside the OEMs, especially if space framed vehicles begin to appear in light trucks, many of whose frames are now made in Illinois and Wisconsin.

In body panels, vehicle program phaseouts endanger five Michigan OEM stamping operations. GM's Conner Stamping and Olds (Lansing) Met Fab #1 facilities and Ford's Dearborn Stamping plant seem at greatest risk. The trend to greater use of some or all plastic panels in vehicle outer skins presents dangers and opportunities. Two of the five at-risk stamping plants, plus several other Michigan plants — OEM and independent — may find new openings in the plastic panel field by the early 1990s.

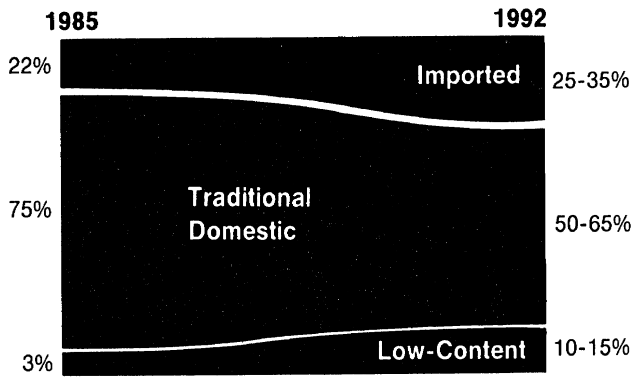
Major Input Sources for Michigan Assemblies



In engines, the redesign of many if not most current programs (see "Emerging Product Developments" below) will likewise present risks and openings. The good news is the reported possibility of siting GM's new 3.2-L V6 engine in the former DDA (now CPC) Romulus facility. Michigan siting of some or all of 1991 4-cylinder Manhattan engine production is a strong possibility. Chrysler's Trenton Engine plant is adding a 2.5-L to its current 2.2-L line, and a 3.9-L V6 truck engine is planned for Mound Road. Ford's Dearborn Engine Plant has received significant investment in its 1.9-L line, and even exports some engines to Europe. On the negative side, the trend to more and more use of aluminum blocks and especially cylinder heads may be a high-cost event for Michigan. Some of GM's and all of Chrysler's Michigan-assembled engines have heads from Mexico, Brazil, or Italy. Blocks for Buick's (Flint) 3.0- and 3.8-L V6s are being moved out of Pontiac's foundry (which closes in 1986) to Defiance, Ohio; foundries in Indiana and New York also appear to have an edge over Michigan facilities in aluminum casting experience.

In automatic transmissions, Michigan is the nation's dominant state. GM HydraMatic facilities supply most GM cars and light trucks; Ford's Livonia plant provides most of the company's large car automatics. Only Chrysler, with transmission plants in Indiana and New York, lacks a presence here. None of this is likely to change much; domestic market share will determine volumes and hence risks. In manual transaxles, installed in over half of small cars, the state has no presence at all. GM gets its domestic manual from its own and Warner Gear's plants in Indiana, and imports some from Isuzu; Ford buys from Warner, Ford of Europe, Temec (Mexico), and Mazda; Chrysler makes its own manuals, but in Syracuse, New York. The trend to front wheel drive benefits transmission and hurts axle plants; Michigan has many of both.

Finally, the outlook is not terribly bright for significant new component orders for Michigan suppliers from the new U.S. plants of foreign-based automakers. While Honda has announced and Mazda is considering U.S. engine plants, the typical foreign-nameplate U.S. operation imports engines and transaxles, and stamps on-site using mostly Japanese steel. Often, new foreign-based suppliers come with these assembly plants, adding jobs but also competing away Big Three business from established Michigan suppliers. At NUMMI in California, 1450 parts are shipped from Japan and 400 are U.S.-sourced. Of the latter, many are low-value added, energy-intensive inputs (sealants, paints, wire and cable), while many of the rest (e.g., air conditioners) are supplied by U.S. plants of Japan-based suppliers.



Manufacturer-Supplier Relations

There will be substantially increased outsourcing by the OEMs, and a shakeout of independent part suppliers. The resulting supplier base will have fewer and larger firms, arranged in tiers under producers of complete subsystems or "modules." While these first-tier module suppliers will tend to cluster around assembly plants — a plus for Michigan — only the most cost-competitive and technologically sophisticated among lower-tier suppliers are likely to survive in the emerging setup.

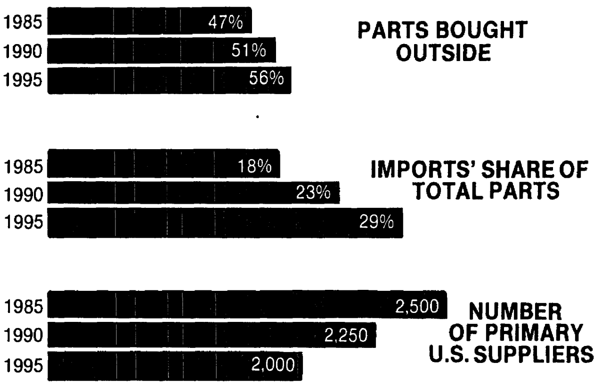
The internationalization of automotive competition is creating pressures for significant and rapid cost reductions, and as a result OEMs and major suppliers alike are shopping more, and more selectively, outside their own boundaries. The OEMs all intend to reduce their vertical integration, citing the fact that in Japan the typical OEM builds very few components in-house beyond engine and drivetrain.

Five developments — the end of secure contracts to captive parts plants, the need for world-class quality, the desire to use Just-in-Time (JIT) methods to reduce inventory costs and quickly identify defects, the possibility of shifting to or sharing with independent suppliers the responsibility for component design and engineering, and the decision to try to source pretested modules rather than only discrete parts — are driving the emerging set of relations between OEMs and their suppliers.

All of the Big Three OEMs have committed to reducing the cost of light vehicles by approximately $2,000 per unit, with initial emphasis on smaller cars. With 30 to 70 percent of the value of each car originating outside the OEMs, it makes sense to seek some, if not most, of the $2,000 in sought-after saving in purchased inputs, while making parallel efforts in in-house stamping, assembly, engine, and transmission operations.

To reduce costs, rationalize delivery, improve quality, and reduce inventory carrying costs, the OEMs have decided to reduce their number of direct suppliers and to press for a more explicitly tiered arrangement in which they deal with a smaller number of first-tier suppliers, which in turn ride herd on a larger number of lower-tier suppliers. Wherever possible, the first-tier suppliers will deliver not discrete (loose) parts, but completed, built-up subassemblies or "modules," such as an instrument panel, a front suspension, or a wheel-brake-tire "corner." Such modules will be delivered on a JIT basis, pretested.

The Coming Shakeout Among U.S. Auto Suppliers

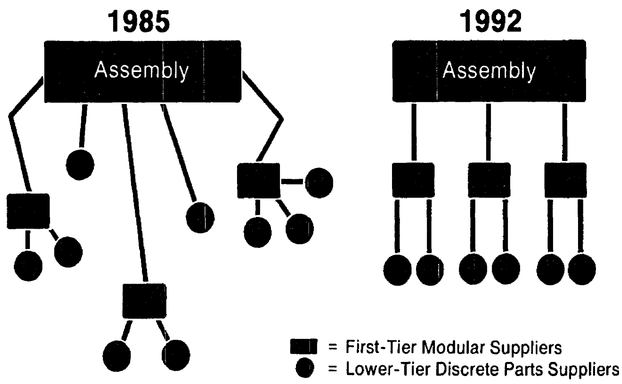


DATA: ARTHUR ANDERSEN & CO.

The module supplier will have significant responsibility for the design and engineering of the module, and to remain a first-tier supplier will continually have to find ways to deliver the subsystem more cheaply. Early cooperation between such suppliers and their OEM customers will be crucial if the modules are to be combined efficiently into high-quality vehicles. That cooperation will include supplier-OEM electronic links, particularly in the computer-aided design (CAD) area.

Such shared design and electronic linking cuts two ways for Michigan. First, to the extent that it makes possible lower levels of OEM vertical integration, it results in lost business for Michigan's many captive supplier facilities. On the other hand, the advantages of proximity to customers for JIT methods suggests that the state will be home to more and more first-tier module suppliers. To complicate things further, however, those first-tier Michigan supplier operations may be reduced to mere subassembly sites or even, in some cases, warehouses; the real manufacturing activity — casting, machining, stamping, extruding, molding, etc. — could be done in lower-tier suppliers outside the state. Finally, electronic linking makes possible, though not inevitable, the outsourcing of certain engineering and design work that traditionally has been sited close to OEM headquarter locations.

Fewer Suppliers, More Explicitly Tiered



On balance, we believe that the coming tiering of the supplier base bodes well for larger, more technologically sophisticated Michigan partsmakers and engineering services firms, but on balance ill for smaller and less technically able producers. First-tier module suppliers will retain significant manufacturing activity (though Ohio and Indiana locations are nearly as functional for JIT as Michigan sites), but they can be expected to react to OEM price-cutting pressure by sourcing the constituent elements of their modules more widely, including to shops in Mexico and the Pacific, something made more feasible by declining transport and electronic communication costs.

While the trends described above seem inevitable, the rate at which they occur, and the extent to which they benefit or harm Michigan, are not fixed in stone. The continued "political" power of captive parts plants places some (though decreasing) limits on the extent and rate of OEM outsourcing. The degree to which full JIT implementation (first-tier supplier plants adjacent to assembly customers) is required is very much in doubt; to the degree that OEMs instead use JIT not as a quality driver but only to shift inventory costs to suppliers, the result could be more Michigan warehouses rather than production operations.

In any case, some work now done in Michigan is likely to be lost to foreign sourcing, including drum brakes, simple steel wheels, interior fabric and soft trim, small plastic parts, small metal stampings, and labor-intensive subassemblies such as copper wire harnesses. There is, of course, some possibility that such work could return to the U.S. and Michigan in the future, as technology reduces labor content and parts complexity. Worrisomely, some of the Michigan independents most likely by virtue of their size and technological capabilities to be future first-tier module suppliers now make some of the parts and components most likely to be foreign-sourced.

Finally, while on average Michigan's large and small suppliers are as competent in engineering as their out-of-state competitors, there is evidence that medium-sized Michigan suppliers may be lagging technologically. This is a problem that needs immediate attention, if such shops are to win contracts from first-tier suppliers.

Implication: Build Modular Sourcing Chains

- Retain and attract 1st tier module suppliers
- Increase technical capacity of lower-tier suppliers

Labor Relations

New, flexible technologies and increased competition—from abroad and from new foreign-owned assembly and parts plants — are likely to produce turbulence in the State's labor relations climate. Traditional work practices will continue to be eroded, and defended. Long-stable pattern bargaining relationships will give way to multiple agreements more tied to the competitiveness of particular plants and product lines.

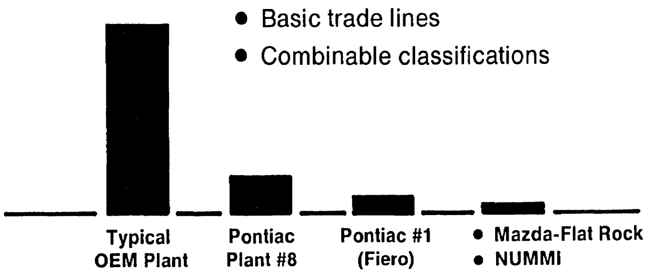
The period between now and 1992 is likely to see turbulent labor-management interactions. Common interests in maintaining and reclaiming market share lost to imported vehicles and parts will be a powerful motivator of "deals" in which labor trades wage moderation and work rule flexibility for management commitments to invest, and keep work, in existing organized plants. But increased international competition will mean more outsourcing. That, along with new U.S. parts plants of foreign-based firms, will produce pressures to pay small car and parts workers less than large car workers.

The State interest is neither in breaking pattern labor agreements nor in freezing existing arrangements, but in promoting labor-management deals covering investment, pay, and work organization. To promote and incentivize such deals, the State needs to promote a wide discourse on the relationships between technology, skill requirements, and production costs; between work practices, costs, and flexible automation investments; and between pattern bargaining, costs, and the future of automotive sector trade unionism.

New technologies are increasing the skill requirements of most production worker jobs in OEMs and first-tier suppliers. On the other hand, machinists' and diemakers' traditional crafts are being devalued, while machine repair tradespeople, millwrights, and pipefitters are so far little affected. New skills are required in both hydraulics and electrical trades. Because recent umpire decisions permit a growing share of relatively routine diagnostic work on electrical/electronic hardware to be performed by production workers, the trades' share of auto jobs is likely to stay constant at about 18%.

Under the pressure of increased imports and outsourcing, many work rule "horror stories" have been cleaned up since 1980. In the OEMs, the least movement has occurred in large car plants and in captive facilities producing their parts. The key, of course, is the effect of workforce flexibility on costs. How much do restrictions on how management deploys workers matter? Which relaxations would save the most money? In which kinds of plants? How much? Enough to change any significant component or vehicle sourcing decisions? Are there investments in programmable automation that would be justified if work practices were changed?

Classifications and Lines of Demarcation

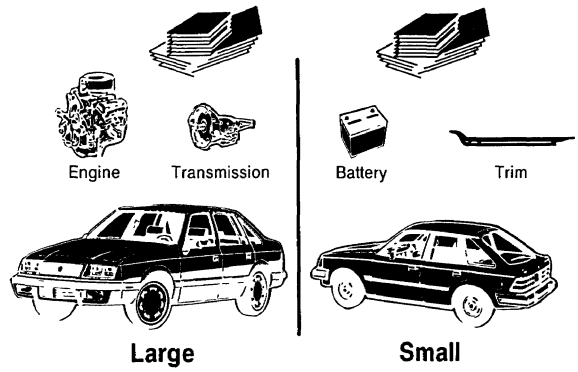


Skilled Classifications Populated

Existing work practices are, of course, a response to the traditionally low levels of job security within the industry. Where in Western Europe and Japan job security is more uniformly underpinned by government policy and tradition, respectively, rigid job-protecting local work rules have not evolved. This logic gives reason for optimism that if and as the U.S. industry comes to treat hourly labor more as a fixed cost, resistance to flexible workforce deployment may diminish. The new Job Opportunity Bank program is the latest and most thorough-going evidence of an evolution in this direction: not only does it represent a new level of job security, but also explicitly trades that for fewer restrictions on the assignability of "Banked" employees.

Heightened competition is eroding more than traditional work practices; negotiated wage and benefit patterns are also under attack. More and more supplier plants have been split off from master agreements, and there is talk of similar pattern breakout among OEM captive parts plants. Certainly, new competition from the U.S. plants of Japan-based suppliers is creating pressure in this direction. The 1982 and 1984 UAW-Big Three contracts permit terms of the national agreement to be waived in cases in which "major outsourcing decisions" hang in the balance. Captive parts plant workers are likely to see lower starting rates, slower progression to maximums, and longer benefit grow-in periods. In addition, we expect OEM parts plants producing at-risk components (some trim, batteries, bearings, die castings, small assemblies, etc.) to negotiate lower-cost agreements than assembly, stamping, engine, and transmission plants; this tiering could occur in 1987 bargaining, but is more likely to come in little by little over the next six or so years, driven by competitive developments in specific product lines.

Tiers in Future Contracts?



There is also some, though less, chance that small car assembly, engine, and drivetrain plants may come to constitute a lower contract tier. As of now, it appears that pay and benefits will be similar, but that there will be few if any restrictions on work organization. It is likely that whatever arrangements eventuate at NUMMI, Mazda, and Saturn will set the post-1990 pattern for small cars, and become the *quid pro quo* for future domestic small car investments, including the domestic programs (if any) that replace Escort/Lynx, Omni/Horizon, Encore/ Alliance, and GM J-bodies.

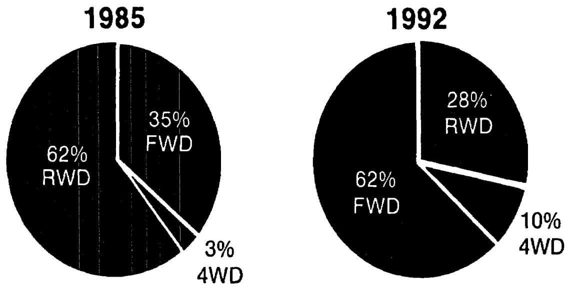
Emerging Product Developments

By 1992, most new cars and many light trucks will have front-drive, new engines with much more aluminum, simpler and higher-quality transmissions, and far more electronic controls than today. Some 15% will have space frames with plastic panels, a configuration that may dominate by 2000. Impacts on engine, mechanical control, steel, and stamping plants are thus likely.

The market itself is an increasingly significant driver of the product decisions made in the Michigan corporate and technical centers of the Big Three and their first-tier suppliers. Increased international competition is shortening product cycles, creating new requirements for product differentiation, and splitting the U.S. market into high-volume "commodity" and lower-volume specialty segments. Technology is playing and will play a growing role in all three of these areas. Unless new world-class quality products that fit the new market demands can be produced at competitive cost, a major shrinkage in domestic market share is assured.

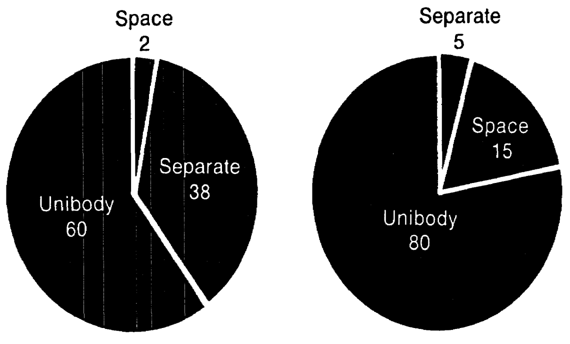
In drivetrains, most passenger cars and many vans will be front wheel drive by 1992, with resulting increases in demand for CV joints. Over time, electronic controls will replace many hydraulic controls, and more McPherson strut front suspensions will be used to accommodate transverse engine/front drive. More four wheel drive vehicles could mean major new opportunities in prop shafts, U-joints, and sophisticated transfer cases. More manual transaxles will be used, with negative impacts on Michigan, with five speeds dominating. By 1992, if belt manufacturability problems are solved, some cars up to perhaps 2.5-L may be equipped with continuously variable transmissions (CVTs), with resulting opportunities in belt-making and viscous dampers but some impacts in gears, friction surfaces, and clutches.

Continuing Trend From RWD in Light Vehicles



Continued movement away from separate body frames in passenger cars and low-load light trucks is likely. By 1992, moreover, use of bird cage or space frame structures will have moved out of low-volume applications (Corvette, Fiero) into several high-volume vehicles. This will greatly increase the chances that many more vehicles will have bolt-on plastic body panels for part or all of their outer skins (see "Automotive Materials" below). On-site steel panel stamping will be used increasingly for new assembly plants, though major impacts on OEM regional stamping facilities are not expected before the mid-1990s.

Separate Body Frames Giving Way to Unibodies and Space Frames

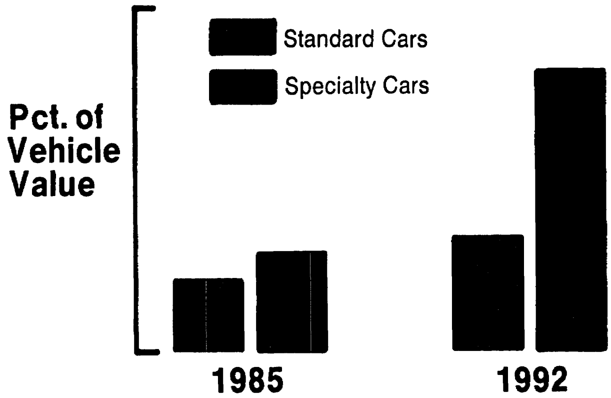


Passenger Cars

Gasoline engines will be extensively redesigned between now and 1992, and even more in the 1993-2000 period. Four-cylinder engines will maintain their roughly 50% market share, but the six/eight mix — now about even — will move to about 35/15 in 1992 passenger cars. Greater use of aluminum blocks and especially cylinder heads is expected. Electronic controls, overhead cams, fast burn combustion chambers, and roller lifters are expected on an increasing share of U.S.-made engines by 1992. Ceramics may begin to play a role in cam followers, piston crowns, valves, and exhaust port liners, though their biggest contributions may come in heavy duty diesel applications. Flexible automation and the possibility of integrating casting and machining operations together may make economic much smaller engine module sizes than today's 400,000-unit floor (see "Production Technologies" below).

Electronic componentry is taking off. Some 12% of the value of 1992 passenger cars will consist of electronics; for the high-volume "commodity" segment, the figure will be 6-8%, while lower-volume specialty segment cars may be 15-25% electronics by value. While much of the latter segment's additional use will be in "gadgets" and luxury features, concepts proved out in these lower-volume applications may spawn greater future use of more functional electronic features in high-volume vehicles. Michigan producers of hydraulic and other mechanical controls will face declining business opportunities, particularly after 1990.

Accelerating Use of Electronic Components



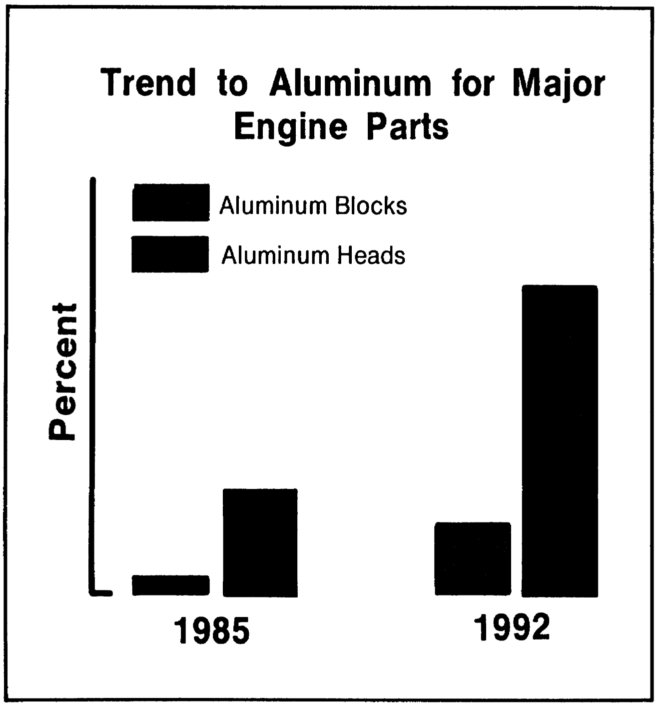
A major engineering challenge is presented by the changes described above. There is a shortage of trained, experienced, systems-oriented people in the design and manufacturing areas. In some departments, such as electrical systems design, 100% of engineers already have CAD workstations; in other departments, however, the figure is as low as 5%. Increasing competence in techniques such as finite element analysis (FEA) is apparent at all three OEMs, and there was broad understanding — if as yet little action — that there needs to be greater use of FEA/kinematics/simulation in earlier stages of the design process. Except in the ceramics area, materials technology may be an area in which the U.S. enjoys a lead over its Japanese, though not necessarily its European, competitors.

Automotive Materials

Huge increases in electrogalvanized steel demand between now and 1992 will give way, by the late 1990s, to much wider use of plastics in car bodies. This will imperil some steel and stamping facilities, but create an opening for a huge new automotive plastics industry in the state. New engines will embody far more aluminum and less cast iron, endangering many Michigan foundries and raising the odds of increased offshore sourcing.

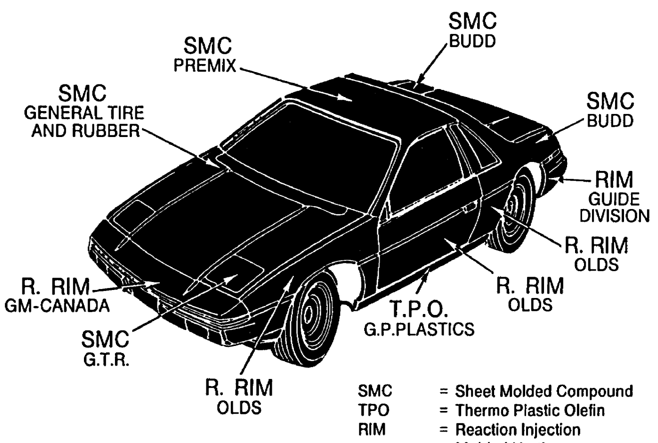
As the average weight of U.S.-made cars has declined from 3800 pounds to 2800 pounds between 1975 and 1985, half the iron, a quarter of the steel, and a third of the copper has been removed. The period between now and 1992, and even more the years 1993-2000, will see a materials revolution of even greater impact. A major drop in carbon steel is in the offing, with galvanized body steels enjoying a boom as automakers move toward greater corrosion resistance. Demand for electrogalvanized steel could exceed five million tons by 1988; that could be nearly twice the current U.S. capacity to produce it, creating opportunities for Michigan steelmakers but also an invitation to greater imports. (There is also the discomforting possibility that the galvanized steel boom may be of limited duration, if plastic skinning comes to dominate post-1995 new vehicle designs.) In the next decade, at least, galvanized steel demand may be the salvation of many U.S. sheet steel makers, some of which could even give up some of their noncompetitive operation in favor of cold strip "market mills" with galvanizing facilities that buy hot band from integrated mills.

There is likely to be increased aluminum usage in cylinder heads, intake manifolds, and — to a lesser extent — engine blocks. In the case of cylinder heads, this will present opportunities for Michigan casting operations, but also risks of lost business to such foreign sources as Fiat-Teksid (maker of most of Chrysler's aluminum heads) and to more experienced domestic sources in Indiana and New York. Wheels and possibly radiators are among other applications in which increased aluminum usage is predicted, with mixed implications for Michigan companies. The state's concentration of iron foundries, captive and independent, suggests some significant negative impacts for establishments that do not quickly master aluminum casting technologies.



Even more revolutionary in its potential future impact is the accelerating use of engineering plastics in a widening range of structural and decorative applications. As many as a million light vehicles may have mostly or entirely plastic outer skins by 1992, and many more (perhaps 50-70%) by 2000. This would have obvious implications for steel demand, for stamping plants and presses, and for diemaking establishments in the state. It will also present major openings for new business in molding, patternmaking, heavy presses, and the like, openings that may not, however, be filled by Michigan firms.

1984 Fiero Body Panels



SMC	= Sheet Molded Compound
TPO	= Thermo Plastic Olefin
RIM	= Reaction Injection Molded Urethane
R. RIM	= Reinforced Rim

Product differentiation possibilities expand at low cost with the use of plastic panels: common mounting points allow different panels on the same space frame, and tooling costs for plastic are about half those for steel, permitting 3- rather than 6-year reskinning cycles. Even more exciting from a cost reduction standpoint, significant parts consolidation is permitted when a properly-designed plastic part replaces several welded subassemblies; this could revolutionize seats, underbodies, and fuel tanks in the 1990s.

Beyond plastic skins, bumpers, headlamps, springs, and perhaps fuel tanks are all areas in which plastics promise to make major inroads. In the bumper and fuel tank areas, this could mean significant negative impacts for certain Michigan OEM plants, while presenting new opportunities to others and to certain independents: stamping press and molding press companies, and makers of tooling for stamping dies and for plastic molds, are not typically the same firms.

Production Technologies

New advances in programmable automation promise a more competitive state automotive economy, and make plausible a Southeastern Michigan "Automation Alley." These advances also pose mighty challenges for Michigan machine tool and tooling firms; in the near term, at least, much more offshore sourcing will be seen in major production systems. If, however, Michigan firms can master the new technologies, especially in the software area, a wealthier "CIM Economy" is possible in the 1990s and beyond.

Emerging technological changes will be the major determinant of whether the U.S. remains the dominant producer in its home market. Those changes will also do much to determine where new facilities are located, which existing plants survive, how large new component and vehicle modules will be, the relations among tiers of producers, and the demand for labor and its skill requirements. The trade and popular press already trumpet a CIM (Computer Integrated Manufacturing) Economy; the extent to which reality catches up with the rhetoric and islands of automation become integrated systems, will write the industry's history. It could provide the basis on which the equities of all stakeholders are preserved in a more competitive future, or simply be disruptive and expensive without reducing costs enough to restore competitiveness.

Flexible manufacturing systems can deliver both adaptability (the ability to sequence serially different designs within a part family without equipment resetting) and convertibility (the ability to switch between, say, six- and eight-cylinder blocks), and so allow component plants to achieve high productivity despite highly variable day-to-day and week-to-week volume requirements for particular products. In bodies, flexible assembly promises to permit a wide range of body styles to be produced on the same line with the same equipment, which includes robotics and AGVs, and to convert a line much more quickly. This would allow elimination of mobile work assignments, solving the problem of fabrication time differences between modules.

Michigan automation suppliers are at various levels of readiness to play on this field. Some are strong in dedicated systems that may suffer as flexible equipment takes over. In other cases, e.g., machine vision, Michigan is emerging as a leader; in robotics — particularly complete systems — the state is also doing well. The vision of a southeastern Michigan "Automation Alley" is increasingly plausible.

Increasing use of aluminum rather than iron castings is about to be accompanied by major technological shifts within aluminum casting, away from permanent molds and toward lost foam and similar processes that aim at smoother and more repeatable surfaces, more cast details, and hence less subsequent machining time. Mastery of lost foam technology could speed conversion to all-aluminum engines, with Michigan impacts already noted.

Among the keys to more flexible assembly is the emergence of adhesive bonding to replace some welding operations. Use of galvanized and zinc-coated steels and of plastic composites can be expected to increase the trend to adhesives. This will have potentially serious impact on Michigan producers of welding guns and other equipment, and may cut electricity demand considerably.

The data communications requirements of flexible systems present a major challenge to the state's many machine tool companies as well. Nearly 30% of 1986-92 automotive automation spending will be in the communications area, as machines and islands of automation are joined together and with management information systems into true CIM. Yet the state's two largest machine tool companies (as of mid-1985) employ 38 programmers between them; clearly, the missing link in these companies' systems capability is in software skills. Michigan firms, many of which began as tool, fixture, or die builders and later made the move to dedicated transfer machines, got good at meeting OEM purchasing departments' low-bid and fast-delivery demands (often producing to OEM-supplied process specs) but not at supplying leading-edge technology. Meanwhile, European and Japanese machine tool makers — many owned by auto OEMs — were used as laboratories as well as job shops. This explains the increasing import share in flexible systems, as well as one U.S. OEM's equity purchase in a European-based automotive machine tool company.

Tooling firms are going to have to move quickly into NC and CAD/CAE if quality and productivity are to improve. Smaller outfits are likely to lack the skills and capital to make the move, and those that survive may do so by forming consortia in which some concentrate on providing CAD/CAE services, others on prototype tooling, others on NC machining, and still others on construction and tryout.

Challenges to Machine Tool and Tooling Firms

Machine Tool Makers...

- Lack software and systems integration expertise

+ Enjoy growing support from new software and machine vision firms

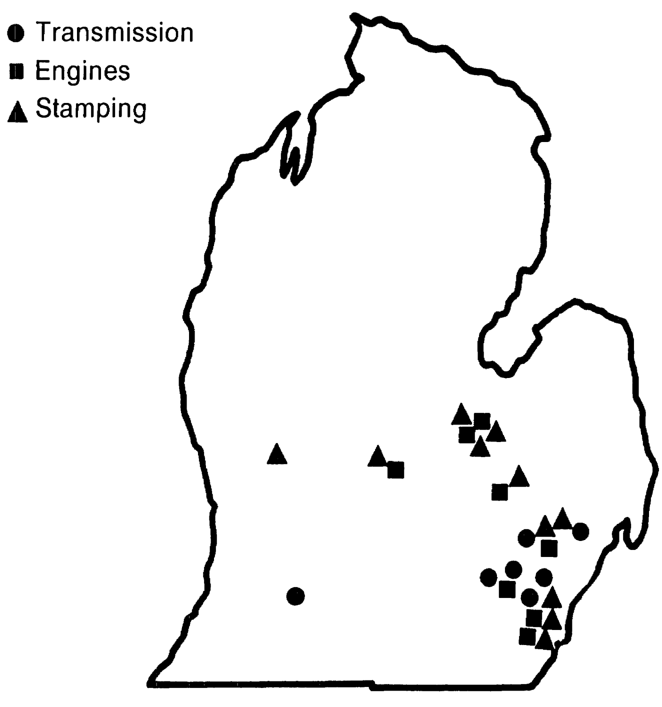
Tooling Industry...

- Needs rapid gains in NC and CAD/CAE competency

+ May be helped by consortia to pool adjustment costs

These and other emerging flexible technologies have implications for facility size, capacity, and location. If programmable automation really helps achieve economic production at sharply lower volumes than today's dedicated lines, it could signal the breakup of large centralized parts plants. That would spell trouble for Michigan's many regional foundries and engine, stamping, and transmission plants. On the other hand, more and more vehicles may be produced in low-volume runs, making it impossible to justify multiple sets of tools for decentralized part/module production at or adjacent to most assembly plants.

Michigan's Dependence on Regional OEM Component Plants



Computer-Based Manufacturing

- CAD/CAE
  - All electronic components CAD-designed in 1985
  - 60 - 90% of tooling and die work by 1992
- Computer-Integrated Manufacturing (CIM)

Who We Are and How We Work

The AIM Project is a team of researchers, policy leaders, consultants, and local economic developers working to understand the concrete implications for Michigan of a changing automotive industry. A six-person central research team (CRT) whose work is overseen by an advisory board of top-level industry, labor, and local development representatives sets the research agenda. Working in parallel with the CRT, a database development team coordinates an information-gathering effort involving local economic development agencies around the state. The current CRT and core Project staff includes:

Daniel Luria
AIM Project Director
Senior Researcher
Center for Social and Economic Issues
Industrial Technology Institute

David E. Cole
Director
Office for the Study of Automotive Transportation
The University of Michigan
Transportation Research Institute

Michael S. Flynn
Researcher
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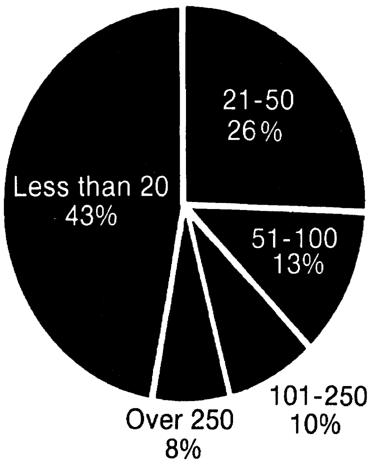
AIM Database Activities

Working with sixteen local economic development agencies in twelve areas of Michigan, the AIM project has been able to supplement the State's existing database of auto-related establishments with detailed information on nearly 1,200 Michigan shops that answered our 1985 survey.

The next issue of the AIM Newsletter will focus on the survey results for a number of local areas. The four charts below give a sense of the type of information gathered. All four represent statewide data.

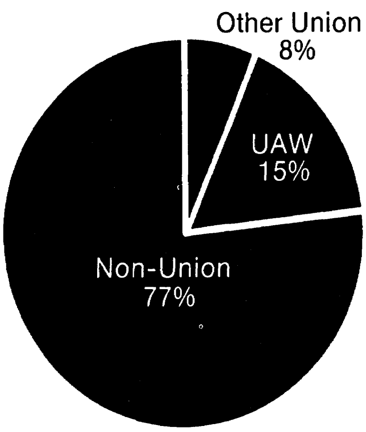
Forty-three percent of Michigan's auto-related establishments have fewer than 20 workers.

Employee Size

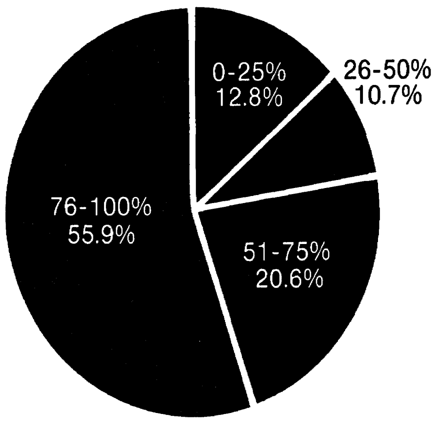


While the majority of Michigan's auto-related *workers* are unionized, more than three-fourths of the state's auto-related *establishments* are not.

Unionization

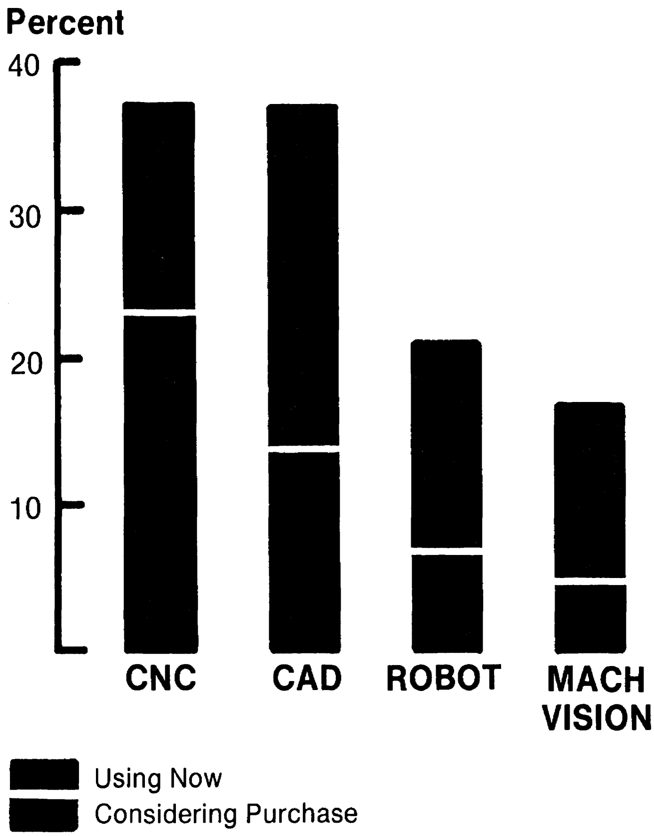


Most Michigan shops that participate in the auto industry are heavily dependent on it. For 56% of responding firms, auto constitutes 76-100% of their sales.



Pct. of Sales Related to Auto

Finally, many Michigan auto-related establishments have ambitious technology implementation plans.



By the late 1980s, 37% expect to use CNC and CAD, 21% to use robots, and 17% to employ machine vision for inspection.

NEWSLETTER
The Auto in Michigan Project
A State of Michigan Program with the
Office for the Study of Automotive Transportation
University of Michigan
Volume 1, Number 2 March, 1986

AIM has had a significant impact. State Commerce Director Doug Ross has created an Auto Policy Group consisting of himself and top Commerce Department executives. In addition, the Commerce Department has formed a larger Auto Working Group whose membership includes industrial agents that regularly work with Michigan auto-related firms. Both bodies are meeting regularly, and have been extensively briefed by AIM project staff.

The project staff has been busy disseminating our findings. This is the second edition of our quarterly newsletter; it is being widely distributed in State and local government, community colleges, and economic development agencies. Last year, we worked with sixteen local economic development agencies in twelve areas of the state, they administered a survey in their areas to all of the auto-related establishments we could identify. Since January, the project has added six new local development agencies to the effort, and they have launched the survey in their areas. Thus, by fall we expect to have a reasonably representative picture of nearly all of the state's automotive endowment. This will allow the State to identify areas of strength (e.g., successful transitions from mechanical to electronic controls by small firms in one area) to be nurtured, and areas of weakness (e.g., slow adoption of CAD in small tooling firms in an area) to be addressed. A stronger supplier base, of course, is key to maintaining high levels of Michigan parts and labor content in North American-assembled vehicles.

Research Continues

AIM research has been a continuation of work begun in 1985. However, though we have retained most of the categories of inquiry used last year (vehicle program siting, major input sourcing, product developments, manufacturer-supplier relations, labor relations, materials, and process technology), in many cases we have narrowed our focus to get richer detail on likely Michigan impacts.

In the *Vehicle Program Siting* area, we continue to track the trade press and keep our ears to the ground on new developments. We try to maintain our own up-to-date product plans by manufacturer, and to estimate how possible developments (e.g., the rising share of "transplant" small cars in the U.S. market) may affect facility choices and capacity needs. We are also attempting to extend product tracking to major powertrain and drivetrain programs; Michigan is even more dependent on regional engine and automatic transmission plants than it is on vehicle assembly.

In the *Major Input Sourcing* category, we are trying to keep up to date on frame, forming (stamping/panel), powertrain, and drivetrain sourcing for Michigan-assembled light vehicles. In addition, we are trying to extend this effort to vehicle programs with no Michigan assembly plants but which rely on Michigan component plants for major inputs — in practice, virtually *every* domestic program! We are now attempting to trace the sources of the steering, suspension, and braking systems and the wheels, bumpers, and radiators that go into Michigan-assembled cars and light trucks. Finally, for the powertrains and drivetrains that go into Michigan made vehicles, we are trying to determine the sourcing not just of block and head castings but also of camshafts, crankshafts, intake manifolds, pistons, and con rods and of cases, differential assemblies, torque converters, and prop shafts.

In *Product Developments*, we are focusing on the emerging prominence of electronic control of engine and drivetrain subsystems. Given the state's tremendous concentration of engine plant-dependent suppliers, it is important for State government to have a clear sense of how the "up-teching" of gasoline engines is likely to play out for suppliers. Our work in this area includes the construction of several scenarios of electronic control penetration, by application, and then getting reactions from our Advisory Board members and others. The next step will be to develop, for the leading scenarios, lists of the parts that might be obsoleted by electronics and of those that would be in heightened demand. Finally, those parts lists will be discussed with industry purchasing people and compared to the AIM survey database to work up lists of establishments that stand to gain or lose work.

The *Manufacturer-Supplier Relations* inquiry is being focused on an important but little-studied slice of the supplier function — engineering services. Our first year work revealed clearly that this industry is of major and growing importance to the state. What we don't know well enough is who most of the establishments are, how strong is the logic of their locating here, and whether their presence can help to anchor manufacturing as well as design and prototyping activity. We need to know much more about CAD-to-CAD communication issues and the other key questions that arise at the engineering services-OEM interface. We hope to have some tentative answers in the months ahead. First, we are commissioning the compilation of an engineering services "directory." Second, we are developing and will pilot a set of questions to bring to manufacturing and engineering service firm leaders, plus a phone questionnaire that could be administered to all establishments in the directory.

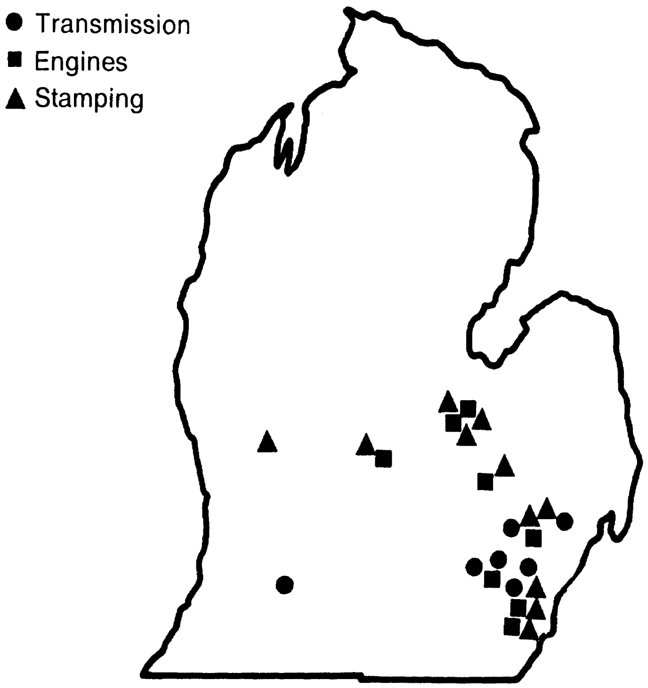
The *Labor Relations* inquiry includes continued data-gathering on innovative new settlements and continued debriefing of union and management personnel. This area also benefits from non-AIM work on technology, work organization, and costs that the AIM project director is pursuing for a federal government sponsor. Moreover, labor-management issues are also being explored in the technology/materials work AIM is doing this year.

That work on *Process Technology* and *Materials* focuses on an engine "track" and a forming "track." Having identified engines as an area likely to see major design and manufacturing changes in the next several years, we are looking in detail at developments in near net shape casting, diecasting, and machining; obviously, materials changes are a major factor in the evolution of all these processes. In forming, driven by our recognition of the maturing steel-plastics competition in body skins (and, increasingly, in structural applications as well), we are looking at tooling technologies and costs, moldmaking, and paintability issues.

Of particular importance will be to assess how new process developments are likely to impact major engine and forming capacity siting decisions. Will changes in casting technology lead to contiguous casting/machining/assembly engine facilities? Could pistons, camshafts, con rods and other engine parts be moved out of most engine plants into their own facilities? What would the implications be for Michigan engine plant workers' employment and skill needs? In forming: How far will the trend toward integrated stamping-final assembly complexes go? What constraints, in what time frame, does moldmaking capacity place on the plastic skinning trend? What is the locational logic of panel-making? Are there new developments in diemaking and press technology that could have major impacts, good or bad, on Michigan steel stamping plants? What are the employment and skill implications? In short, what do OEM and non-OEM engine and forming endowments look like — at the establishment level — under various scenarios for 1992 and 1995?

(continued on pg. 2)

(continued from pg. 1)



Finally, on the research front, we are embarking on some *computer simulation work* using an input-output/econometric model housed by the State Commerce Department at the University of Michigan. This model describes the Michigan impacts of forecasted changes based not only on technical relationships among industries but also on "regional purchase coefficients" that depict Michigan's supply self-sufficiency in each industry. Some of the runs we have commissioned will simulate the sales and employment impacts of (a) less Michigan content in future domestic small cars, (b) more Michigan content in future "transplant" vehicles, (c) the closing of an at-risk assembly plant, (d) the decentralization of some component and forming activities, and (e) a changing materials mix in future domestic cars.

Who We Are and How We Work

The AIM Project is a team of researchers, policy leaders, consultants, and local economic developers working to understand the concrete implications for Michigan of a changing automotive industry. A six-person central research team (CRT) whose work is overseen by an advisory board of top-level industry, labor, and local development representatives sets the research agenda. Working in parallel with the CRT, a database development team coordinates an information-gathering effort involving local economic development agencies around the state. The current CRT and core Project staff includes:

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UPDATED RISK RATINGS OF MICHIGAN CAR AND LIGHT TRUCK ASSEMBLY PLANTS, 1986-1992

Co.	Plant	Current (1986) Program(s)	Risk factor: Age of Program(s)	Attributes of Plant	Cost of Change to FWD	Imports or Out-sourcing	Fuel Prices or Rules	Plant Risk Score
GM	Clark/Fleetwood	B,D	8	7	7	0	2	24
	Pontiac 1	P	1	2	2	5	0	10
	Pontiac 8	G	5	3	5	0	0	14
	Pontiac 5	S10	4	2	0	2	0	8
	Willow Run	H	0	1	0	1	0	2
	Buick City	H	0	0	0	1	0	1
	Lansing	N	1	2	0	6	0	9
	Orion	C	3	2	0	1	0	6
	Flint Truck	C/K,K	6	4	0	0	3	13
	Poletown	E/K	0	0	0	1	0	1
Ford	Wixom	LS, Panther	4	2	4	0	1	11
	Wayne (Truck)	Bronco, F	5	2	0	0	2	9
	Wayne (Car)	Erika	4	0	0	9	0	13
	Dearborn	Fox	7	7	4	6	0	24
Chrysler	Jefferson	K,E,CV	8	7	0	6	0	21
	Sterling	H,P	1	0	0	6	0	7
	Warren	D/W,N	0	2	0	2	0	4

(A "Plant Risk Score" of 10 or higher indicates danger.)

The World Automotive Industry in Transition

AIM Analysis by Dan Luria

The November, 1985 Arthur D. Little study, *The World Automotive Industry in Transition*, focuses on seven emerging developments with major implications for larger suppliers:

The World Automotive Industry In Transition

- **Foreign-owned producers to increase share of U.S. market**
- **Manufacturing plants to be fewer, but larger and more flexible**
- **More outsourcing presents opportunities for suppliers**
- **Product differentiation — a key to winning the new consumer**

November 1985/R851101 Outlook Report

Arthur D Little Decision Resources
Acorn Park, Cambridge Massachusetts 02140
Telephone 617-864-5770

- The supplier opportunities presented by declining OEM (assembly company) vertical integration;
- The likelihood of growth in *surface-level* product differentiation despite greater standardization in structural components (i.e., fewer platforms);
- The increasing irrelevance of name brand and exterior dimensions in both buyer loyalty and sales segmentation; and
- The hints of new OEM-dealer sales/dealer service relationships visible in two recent polar-case developments, the (Porsche — and soon Saturn?) "factory store" and its antithesis, the auto "supermarket."

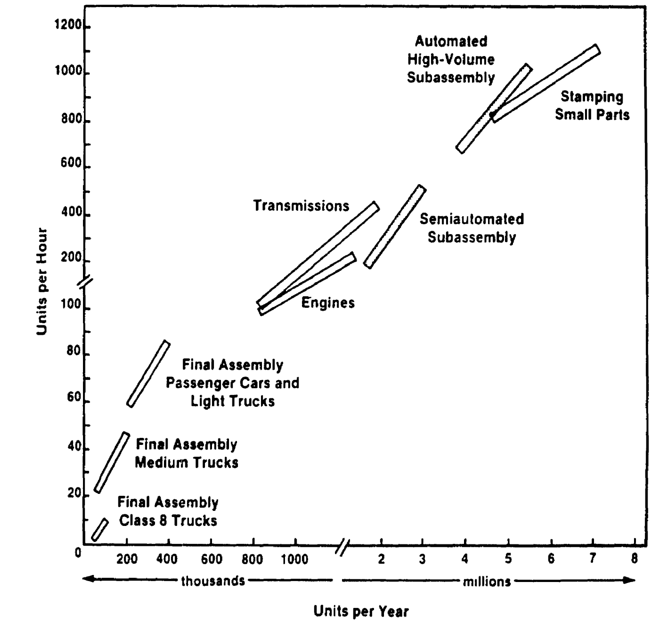
Table 6. Anticipated Late-1980s Foreign-Owned Capacity and Offshore Sourcing of Vehicles

			Optimistic		**Pessimistic**	
	1984		**Late 1980s**		**Late 1980s**	
	MM Units	**%**	**MM Units**	**%**	**MM Units**	**%**
Total U.S. Market	10.4	100	11.0	100	9.0	100
Domestically Produced	8.0	77	7.8	71	5 9	66
U S.-Owned	7 6	73	6.7	61	4 9	54
Foreign-Owned/ Controlled	**0.4**	**4**	**1.1**	**10**	**1.0**	**11**
Imported	**2.4**	**23**	**3.2**	**29**	**3.1**	**34**
Total Share with High Foreign Ownership	**2.8**	**27**	**4.3**	**39**	**4.1**	**46**

Source: Arthur D. Little, Inc. estimates.

- Import and "transplant" (U.S.-assembled, foreign nameplate or joint venture) cars' share for the "late 1980s" is forecast to be 39-46%.
- 1986-95 car market (sales) growth of 2.4% per year for North America. (I predict 0.7-1.5%, and lean strongly toward the bottom end of the range.)
- Projections that, in both assembly and components, typical facility sizes and volumes will increase. (In my view, this may be right, but is at least as likely to be wrong. Flexible machining and assembly automation and developments in casting may permit both huge engine and transmission plants that machine and assemble many different engines *and* a decentralization into small casting/machining minicomplexes; to predict one rather than both outcomes is premature.)

Figure 5. Typical Ranges of Production Rates Per Automotive Plant



Source: Arthur D Little Inc

The dominant fact of the North American market between now and 1995 can be summed up in two words: excess capacity (see pages 6-7). With more and more countries able to produce vehicles and/or major subsystem components of acceptable cost and quality, and with less and less of the North American market protected by preferences for full-size cars, most of that excess capacity is certain to be in the U.S. and Canada. My estimate is that in 1990 North American car plus light truck production capacity, excluding transplants, will only need to be on the order of eleven million units; today, capacity stands at about 13.5 million. Clearly, the successful supplier is the one serving the capacity that will remain — and that requires an understanding of likely future vehicle sales by manufacturer and by segment. Being able to sell to the transplants — Honda in Ohio, Nissan in Tennessee, and so on — is also essential.

This analysis suggests a possible rule of thumb: since the Big Three U.S.-based OEMs are unlikely to commit large sums to projects not relatively certain to survive the emerging capacity wars, when possible a supplier might be wise to adopt a policy of limiting its risk by confining its emphasis to:

- New vehicle program introductions in the less (though increasingly) import-competing segments;
- Joint ventures with the OEMs producing for those segments; and
- Activities giving rise to products or services that can enjoy a market with both the Big Three *and* transplant organizations.

The AIM Project Survey Database

Alan Baum

From its inception, the Auto in Michigan (AIM) Project has focused on obtaining information that could be used by economic development professionals at the establishment-specific level. To achieve this objective, predictions about the industry's future based on interviews with industry leaders have been supplemented by an extensive survey effort aimed at the state's auto-related establishments. This survey was carried out last year in twelve areas of Michigan. It is currently being extended to six additional areas, bringing the vast majority of Michigan auto establishments into the survey sample.

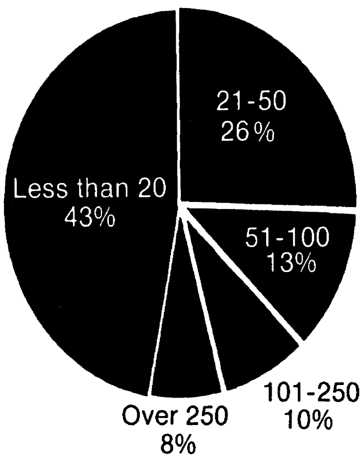
The survey obtained the following information on each establishment that responded:

- Demographics, ownership, and unionization;
- Description of lines of business;
- A detailed description of the parts, tooling, materials, and/or services that the respondent establishment purchases and sells;
- Information on the identity of each respondent firm's suppliers and customers, and the goods and services bought from or sold to each;
- Current and planned technology implementation; and
- Data concerning respondents' views of obstacles to getting or remaining competitive.

The survey has provided new insights into Michigan's most important manufacturing sector.

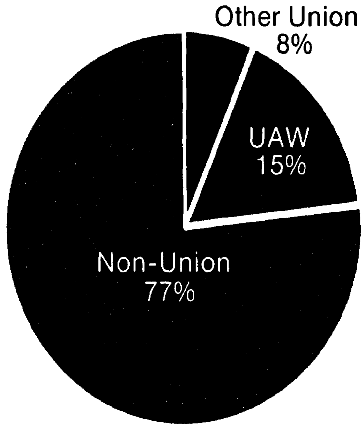
First, Michigan's establishments are overwhelmingly small: 43% have 20 or fewer employees; nearly 70% have 50 or fewer employees. Somewhat surprisingly, these statewide figures vary little throughout the state; the industry is clearly dependent on small shops.

Employee Size



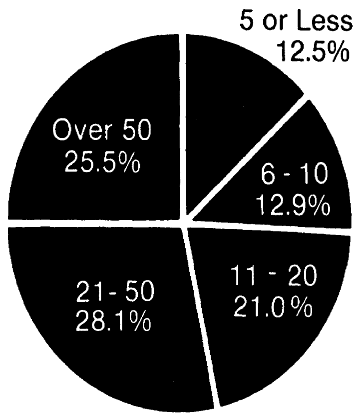
Second, although a majority of the *workers* in Michigan's auto-related industry are unionized, over three quarters of the *establishments* surveyed are not. The level of unionization varies somewhat across the state, with Grand Rapids, Downriver, Oakland County, and Macomb County being slightly less unionized (in terms of the percentage of establishments) than the state as a whole. Of course, establishment size plays a big role: larger establishments are much more likely to be unionized than smaller ones. Even so, 40% of the establishments with over 100 employees are not unionized.

Unionization

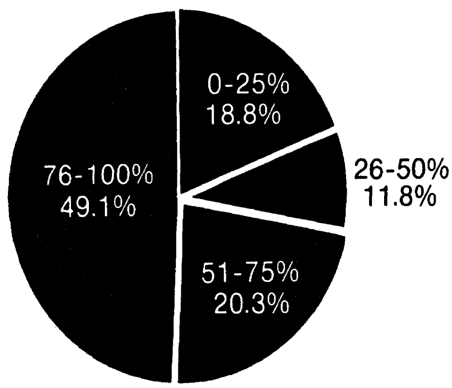


The survey revealed a highly complex and interlinked industry. The average respondent facility reported an average of 25 suppliers, over 70% of them other Michigan establishments. This shows the extreme importance of the auto industry — and not just the large Big Four establishments — to the state.

Establishments Supplying Respondent Facility

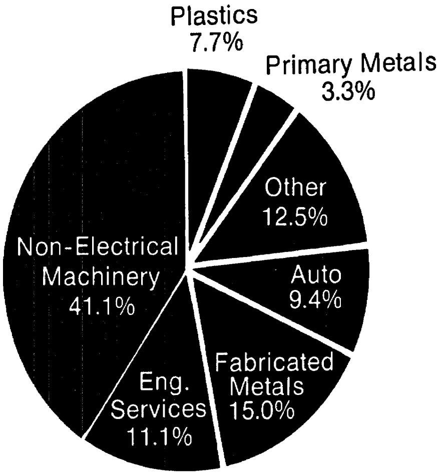


70% of Respondents Report Mostly Michigan Suppliers

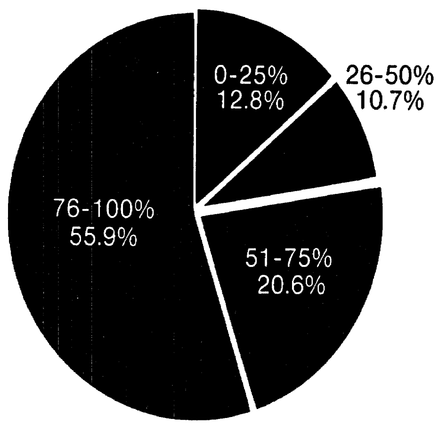


The results have also been useful in showing the distribution of Michigan auto manufacturing by industry type. Although finished parts are important, the results show a large portion of the industry in tool and die work (included below in "non-electrical machinery"). Engineering services and plastics are each relatively small, but growing, segments of the industry. Our results also show the extreme importance of the industry to its suppliers: over 75% of the establishments report that over half of their sales go to auto.

Line of Business by Primary S.I.C.



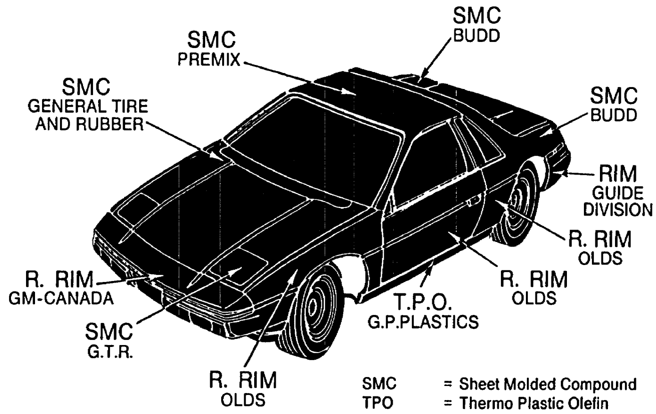
Pct. of Sales Related to Auto



In order to maximize the usefulness of this information, a coding system was devised. It categorizes an establishment's product line by process (assembly, casting, forging, machining, stamping, molding, services, etc.), material used (steel, iron, plastics, rubber, chemicals, etc.), vehicle subsystem (engine, transmission, brakes, etc.), and part (intake manifold, CV joint, etc.). Codes were also established for tooling and other equipment that cannot be classified as discrete parts. This classification system goes well beyond the Standard Industrial Classification (SIC) coding (over 350 part codes alone as opposed to 60 SICs in the auto sector). It can serve a number of uses; a few illustrations follow.

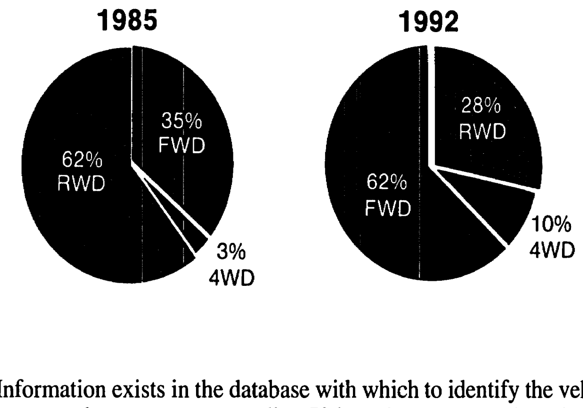
- AIM research has indicated a shift in material usage from steel to plastics in major body panels of many new vehicle programs. The database can be used to identify the large numbers of winners and losers that this shift will affect. Searching on material and part code will produce a list that can be used by state and local economic developers to assist businesses in responding to the risks and opportunities presented.

1984 Fiero Body Panels



SMC = Sheet Molded Compound
TPO = Thermo Plastic Olefin
RIM = Reaction Injection Molded Urethane
R. RIM = Reinforced Rim

- Front wheel drive is becoming the dominant transmission choice, particularly in newer car programs. Certain new parts are required for front drive cars, while other parts will no longer be in such great demand. The database can identify the establishments affected, and provide detailed information to assist businesses producing the gaining and the waning parts.



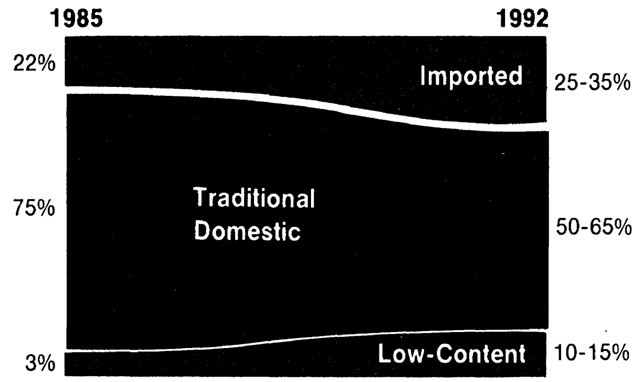
- Information exists in the database with which to identify the vehicle program that a company supplies. If the volume or even the existence of that program is threatened, the suppliers that will be affected by this development can be identified and action taken to minimize the negative impact. Conversely, increases in volume can lead to new opportunities for increased business.
- A *potentially* large supplier market exists with the introduction of new U.S. assembly facilities of foreign manufacturers. Some of these companies are interested in establishing a network of local suppliers, often by having the U.S. operations of their Japanese suppliers hook up with domestic firms. The database enables us to identify both types of supplier that might get involved in such "marriages," and to do so on an individual part or subsystem basis.

(continued on pg. 8)

The Capacity Explosion: Implications for Michigan Suppliers

AIM Analysis by Dave Andrea, Richard Hervey, and Dan Luria

In our first issue, we noted the emerging squeeze on traditional domestic car and light truck sales from imported and "low-content" or "transplant" U.S.-assembled vehicles.



In this issue, we look in more detail at the competition created by the worldwide capacity explosion, and attempt to estimate the impacts on Michigan suppliers.

Market Size

In calendar 1985, North American car and light truck sales totaled 16.94 million units. Careful inspection of thirty years of annual sales data makes clear that 1985 was an excellent one — very close to the top of sine wave-like cycle that characterizes this market. Our view is that that sine wave cycles around a trend line with a slope of approximately 0.8 percent per year. In good years, sales tend to be about two million units above trend; in weak years, about two million below the trend line. We would suggest that in 1985, the trend line — depicting a medium year market — was at the 15 million unit level.

> The recent decline in crude oil spot and contract prices has led some — though not most — auto market analysts to predict higher (trend) auto sales. We would note that in a new car and light truck fleet averaging 25 mpg, even a 50-cent per gallon retail fuel price drop saves a driver just $240 a year over 12,000 miles, or 2 cents a mile. Since total owning-and-operating costs now run about 40 cents per mile, a penny only amounts to 5% of that — probably not enough to affect trend sales appreciably.

Imports + Transplants = Domestic Overcapacity

If all automakers stick to announced plans, North America will host 1.3 million more low-North American content locally-assembled light vehicles than the 540,000 made here in 1985. The table below shows each company's plans for added production capacity of such "immigrant" or "transplant" cars and light trucks. That capacity — and in good years, we believe sales will roughly equal capacity — will nearly double from 1985 to 1987, and then rise another nearly 70% by 1989 before leveling off in the early 1990s.

Joining the transplants will be a growing number of imported cars and, to a smaller extent, light trucks. We predict increased North American sales of Japanese-built cars, but that all of the increase will be in shipments of "captive" imports brought in from Japan by GM, Ford, and Chrysler. Korea will ship many more small cars here, about half as captives. Mexico and Brazil will provide captives to Ford and VW, respectively, and European sales growth will ratchet up with Yugo sales and then flatten. Imported light truck sales will grow modestly; a continued effective tariff rate (U.S.) of 25% is assumed.

Transplant Capacity (000)

	1985	1987	1989	1991
U.S. Cars				
Honda	146	250	360	360
NUMMI	36	200	200	200
Nissan	40	100	100	100
Toyota		40	180	180
Diamond Star		40	180	180
Mazda		40	200	240
Renault	110	100	100	100
VWA	78	80	80	80
Others			40	140
	410	850	1,440	1,590
Canadian Cars	20	70	150	150
	430	920	1,590	1,740
U.S. Light Trucks	110	110	110	110
	540	1,030	1,700	1,850

Where in 1985 imports and transplants combined took 4.5 million (or 26.8%) of a 16.94 million unit North American light vehicle market, by 1991 we expect them to hold 39.4% — 7.02 of 17.83 million in a good year.

Imports Plus Transplants (000)

	1985	1987	1989	1991
U.S. Cars				
Imports (I)				
Japan	2,163	2,450	2,550	2,600
Korea	0	120	220	310
Europe	616	700	730	750
Mexico	0	40	130	130
Brazil	0	30	70	70
	2,779	3,340	3,700	3,860
Transplants (T)	410	850	1,440	1,590
Canadian Cars				
Imports	342	360	380	380
Transplants	20	70	150	150
I&T Cars	3,551	4,620	5,670	5,980
U.S. Light Truck				
Imports	823	845	855	865
Transplants	110	110	110	110
Canadian Light Truck				
Imports	49	55	60	65
I&T Light Trucks	982	1,010	1,025	1,040
I&T Cars and Light Trucks	4,533	5,630	6,695	7,020

While this obviously portends huge sales and employment losses in traditional Big Three vehicles, it must be remembered that, to the extent the increase in imports and transplants comes in captive or joint venture vehicles, profits might actually increase. Our estimate is that of the total increase in imports and transplants (1985-1991) of 2.5 million units, approximately 0.7 million will benefit rather than harm Big Three profitability. The other 1.8 million units, however, may hurt Big Three earnings badly: we look for the Japanese to market directly at the high-profit midsize and specialty segments.

What's Left for the Domestics?

In future good sales years, we expect the allocation of sales among size "segments" not to change appreciably from 1985.

But if overall market segmentation is not likely to shift much beyond business cycle-driven changes, the same cannot be said of import and transplant segmentation. In cars, the Koreans, Mexicans, Brazilians, Taiwanese, and Yugoslavs will ship more subcompact regulars — as will Suzuki, Isuzu, Mazda, and Mitsubishi as suppliers of captives — but the Japanese will react by shipping more and more subcompact specialty, compact regular and specialty, and even (by 1991) midsize cars. This is made possible by the tremendous flexibility of the Japanese OEMs and their first-tier suppliers: in 90 to 120 days, final lines can be shifted from Corollas to Camrys, from Sentras to Maximas, or from Colts to Tredias.

The net result is that by 1989 subcompacts will make up 49.6% of import and transplant volume, down from 54.7% in 1985. And, because sales volumes rise so much, the impact is greater than that 5.1-point shift suggests. In 1985, non-subcompact import and transplant sales totaled 1.61 million units; by 1989, the total will be 2.86 million, an increase of 1.25 million.

The End of Domestic Small Cars?

If we are right, traditional domestic subcompact sales will decline from 1.2 million units in 1985 to just 0.3 million in 1991, even if 1991 is a good year. Traditional domestic compact sales will fall from 2.7 million units in 1985 to about 1.8 million. Thus, even in a strong economy, traditional high-local content domestic small (subcompact and compact) car sales will drop from 3.9 million units in 1985 to 2.1 million by 1991. In addition, partly because some Japanese compacts (e.g., Camry) compete against domestic mid-sizes, larger car sales will be at least 300,000 units lower.

The loss of 1.8 million traditional domestic small cars would have some negative impacts on earnings, but perhaps not severe ones. The impact on employment would be hugely and unambiguously severe. Ten assembly plants' worth of output would be rendered unnecessary, along with two engine, two transmission, and two stamping plants' production, plus hundreds of smaller parts operations, OEM and independent alike.

1985-91 IMPORT & TRANSPLANT CAR SALES AND SEGMENTATION

Segment	1985	%	1987	%	1989	%	1991	%
Sub Reg	1,553,348	43.8	2,050,000	44.4	2,330,000	41.1	2,450,000	41.0
Sub Spec	388,006	10.9	460,000	10.0	480,000	8.5	500,000	8.3
Com Reg	680,471	19.2	970,000	21.0	1,520,000	26.8	1,620,000	27.1
Com Spec	300,750	8.5	410,000	8.9	500,000	8.8	525,000	8.8
Mid Reg	295,177	8.3	325,000	7.0	380,000	6.7	400,000	6.7
Mid Spec	40,587	1.1	80,000	1.7	100,000	1.8	110,000	1.8
Lux Reg	243,206	6.8	265,000	5.7	275,000	4.9	290,000	4.9
Lux Spec	49,289	1.4	60,000	1.3	80,000	1.4	85,000	1.4
	3,550,834	100.0	4,620,000	100.0	5,670,000	100.0	5,980,000	100.0

Implications for Suppliers

Obviously, the shrinking market for traditional domestic (especially small) cars could have significant negative impacts on suppliers. Michigan plants, OEM and independent, that sell to Big Three small car programs need to find other business. A priority is to build bridges to the transplants, either directly or by forming alliances with Japan-based suppliers. Otherwise, these suppliers will use the transplant business to get a toe-hold here, and then move to take Big Three business as well.

Japanese Parts Suppliers With Examples of U.S. Competition

Company	Location	Competitors	Product(s)
Nihon Radiator	Smyrna, TN	Modine, Blackstone	Radiators
Bridgestone	LaVergne, TN	Goodyear, Uniroyal, Firestone	Tires
Nippondenso	Battle Creek, MI	Ford, GM, Blackstone	Radiators, a/c components
Hi-Lex (Nippon Cable)	Battle Creek, MI	Allied, Lucas, Speareflex	Clutch, brake & steering cables
Yazaki	Livonia, MI	Lucas, Allied, Packard	Wiring harnesses
Topy Int'l.	Elk Grove, IL	Kelsey-Hayes, Rockwell, Budd	Wheels
Kanto Seiki	Lewisburg, TN	Gulf & Western, LOF, Hoover Universal	Dashboards, grilles
Izumi	Yaphank, NY	Sheller-Globe, Ford	Steering wheels
NSK	Ann Arbor, MI	FAG, Federal-Mogul, Timken	Bearings
Amer. Koyo	Orangeburg, SC	FAG, Federal-Mogul, Timken	Bearings
NTN	Des Plaines, IL	FAG, Federal-Mogul, Timken	Bearings
KTH	Urbana, OH	Budd, A.O. Smith	Stamped, welded body parts
CKR Ind.	Winchester, TN	Uniroyal, Sheller-Globe, Imp. Clevite	Rubber parts
LeBlond Makino	Cincinnati, OH	Cincinnati Milacron, Ex-Cell-O	Machine tools, flexible mfg. systems
Clarion	Nashville, TN	Delco	Stereos
Nippon Seal	Elk Grove, IL	NOK, Federal-Mogul	Oil seals
Bellemar Parts	Marysville, OH	Hoover Universal, Maremont	Exhaust systems, seats
Tricon	St. Louis, MO	Hoover-Universal, Lear-Siegler Douglas & Lomason	Seats
Calsonic	Shelbyville, TN	AP Parts, Maremont	Exhaust systems
Nippon Sheet Glass	Japan	LOF, PPG	Glass
Marubeni	Japan	Bethlehem, Inland, U.S. Steel	Steel
Mitsui	Japan	Bethlehem, Inland, U.S. Steel	Steel
Yokohama	Japan	Firestone-, Goodrich, Goodyear	Tires
NGK, Hitachi	Japan	Bosch, AC, Ford Champion	Spark plugs
Akebono, Kushiro	Japan	Allied, Lucas, Kelsey-Hayes	Brakes
Topi	Japan	NI Industries, Budd, Kelsey-Hayes	Wheels
Aisan Kogyo	Japan	AC, Holley, Bosch	Fuel pumps, carburetors
Hanshin	Japan	Allied, Delco, Bosch	Ignition coils

Source: *Ward's*, 9-9-85

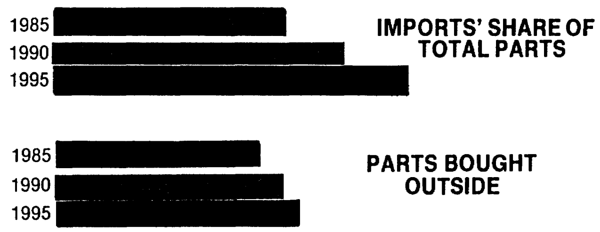
(continued on pg. 8)

Suppliers *(continued from pg. 7)*

In addition, the Big Three are going offshore for more and more of their parts as well as vehicles. We expect Big Three local (North American parts) content to drop from 95% in 1984 to about 86% in 1990. That, coupled with an only modest rise in the transplants' local content, means 21% less work for U.S. — and hence Michigan — suppliers.

Supplier Sales Losses from Offshore Sourcing
(Cars only, U.S. only)

	Total Unit Factory Sales (millions)		Percentage Local Content		Equivalent Unit Factory Sales (millions)		Change
	1984	1990	1984	1990	1984	1990	
GM	4.3	3.4	97%	90%	4.2	3.1	
Ford	1.8	1.4	94	85	1.7	1.2	
Chrysler	1.3	1.0	90	80	1.2	0.8	
Transplants	0.4	1.5	30	40	0.1	0.6	
Imports	2.6	3.7	0	0	0	0	
TOTAL	10.4	11.0	70	55	7.2	5.7	-21%
Memo: Big 3	7.4	5.8	95	86	7.1	5.1	-28



DATA: ARTHUR ANDERSEN & CO.

On the other hand, the Big Three are moving to outsource more of the work now done in-house. While this could have severe impacts on Michigan, which hosts over half of Big Three stamping, engine, and automatic transmission capacity, it *could* mean more work for independent suppliers. As the table below shows, while Big Three equivalent unit sales decline 28%, "outsourced factory sales" drop only 12%.

Supplier Sales Gains from Falling OEM Integration

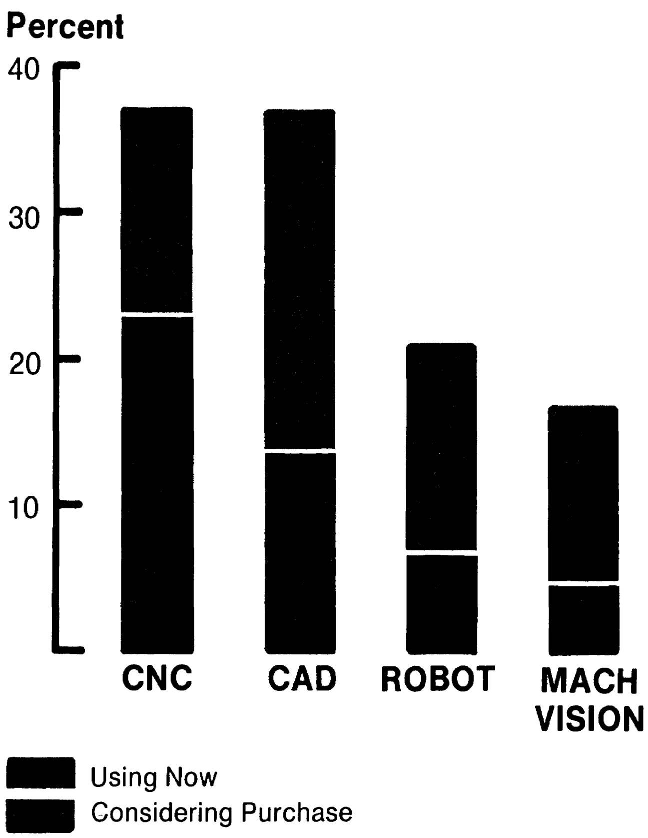
	Total Unit Factory Sales (millions)		Percentage Outsourced		Outsourced Equivalent Factory Sales (millions)	
	1984	1990	1984	1990	1984	1990
GM	4.2	3.1	35%	45%	1.5	1.4
Ford	1.7	1.2	55	65	0.9	0.8
Chrysler	1.2	0.8	65	70	0.8	0.6
	7.1	5.1	45	54	3.2	2.8
	-28%				-12%	

Survey *(continued from pg. 5)*

- AIM has identified emerging sourcing trends in particular parts, and has predicted that many now made in "captive" (Big Four) component group plants are likely to be contracted out to suppliers. This could have a potentially negative impact on the state, since Michigan has a disproportionate share of those captive plants. However, if the business is transferred to independent facilities *within* the state, the net employment impact can be minimized. The database can be used to identify firms likely to benefit from shrinking OEM component involvement.

- Some "regional" plants of the OEMs (those that produce parts for a number of vehicle programs), primarily in the stamping, engine, and transmission area, may be at risk in the coming years. Suppliers to these plants could therefore similarly be at risk. The database can identify these establishments, and corrective action suggested to minimize the impact of the change.

- The use of technology for increased quality and cost efficiency is becoming a requirement for continued contracts with the major automakers, particularly in certain parts. The database includes information on capabilities in computer-aided design (CAD) and engineering (CAE), robotics, machine vision, and other computer-based technologies. The Technology Deployment Service of the Michigan Department of Commerce has already used this information to pinpoint client groups most appropriate for its services.



In addition to the database of Michigan establishments, an "electronic clipping" service has been maintained that summarizes relevant items from the trade press concerning the future of the auto industry, and particularly such references to Michigan establishments. The file is indexed by location, company, publication, and a number of subject categories.

AIM NEWSLETTER
The Auto in Michigan Project
A State of Michigan Program with the
Office for the Study of Automotive Transportation
University of Michigan
Volume 1, Number 3 June 1986

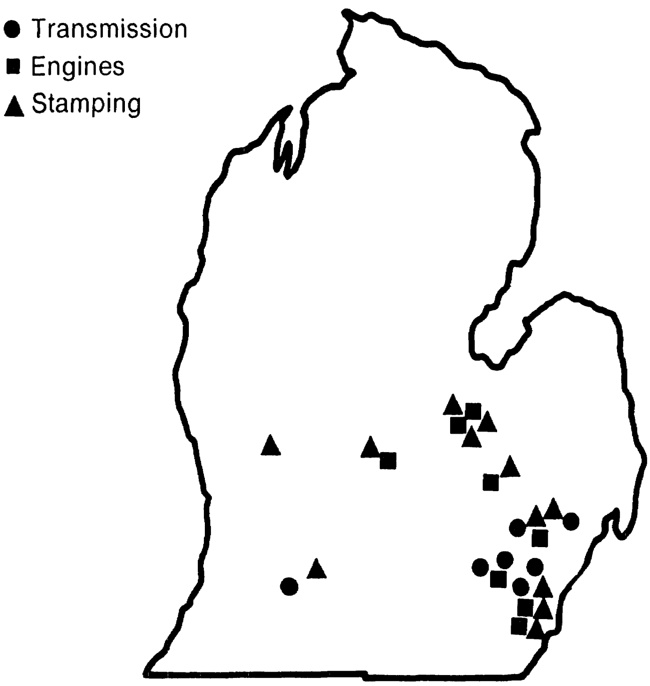
In this issue, we present parts of two studies in progress, one on stamping and one on engine manufacturing. These report on the Project's thinking as of May 1986. Future issues of the AIM Newsletter will update, amend, and in some cases contradict what is presented here. — DDL

Challenges to Michigan's Automotive Stamping Industry

AIM Analysis by Donald N. Smith

Michigan plants stamp the major body panels and steel structural components for about two out of every three cars and light trucks assembled by the Big Three in North America. Several factors identified in our discussions strongly suggest that the Michigan automotive metal stamping industry may experience significantly new competitive conditions in the near future. One result will be to raise substantially the level of automation required. The hundreds of stamping companies in Michigan having annual sales of less than $20 million may find it difficult to amass the capital necessary to acquire the requisite automation. Larger stamping plants owned by the automakers will feel intense pressure from plastics.

The purchase of a new automated press alone will cost at least $1 to $1.5 million, and new large transfer presses can cost several million dollars when fully equipped with appropriate automation. Since most Michigan stamping plants, including the regional plants of the Big Four, rely on stamping presses an average of 30 years old, the typical press plant will require several new presses. General Motors and Chrysler have budgeted about $1.5 and $0.7 billion, respectively, to start press modernization programs for their plants, many of which today use equipment bought in the 1950s and 1960s.



However, just as there are concerns about the viability of the independently owned stamping companies, the Big Four are questioning the future of their captive regional stamping plants, some of which employ as many as four thousand workers. Companies have recently delayed the purchase of additional presses, as they ponder future new car plans, many based on plastic rather than steel body panels, and a growing body of evidence that costs in the captive regional stamping plants are significantly (25-30%) higher than comparable Japanese operations, and 15-25% higher than some U.S. independents' plants.

The captive regionals' cost penalty lies in every expense area: labor rates, equipment amortization, steel cost, equipment utilization and plant throughput, and die costs.

Sources of U.S.-Japan Press Plant Gap

Cost Disadvantage
- High Part Rejection Rate
- High Incoming Steel Rejection Rate
- More Expensive Steel
- More Direct and Indirect Labor
- Lower Equipment Utilization
- More Expensive Tooling

Less Flexibility
- Slow Die Change Time — lengthens part runs
- Abusive Tooling Practices
- High-Cost Tooling — discourages frequent model change

Most observers agree that the Japanese "quick die change" (5-15 minutes versus 3-6 hours in large U.S. press plants) is a major productivity factor. Another is the rationalization of production planning based on the assignment of a family of parts to the same plant for long-term commitments, thereby permitting the captive or independent plant management to justify a high level of automation, specially fitted to the relatively narrow characteristics of the family. This contrasts sharply with U.S. automaker procurement practices, where contracts with independent stamping companies for stamped parts historically have been for a year at a time, with few attempts made to channel part *families* to particular companies.

In the absence of this specialization, independent companies have been forced to purchase relatively expensive general-purpose automation, which could be flexibly adapted to different families of parts that *might* be ordered by the automakers in the future. Faced with these uncertainties and the absence of long-term commitments, few independently owned stamping companies in the United States could justify investing in the level of modern automation used by their counterparts in Japan. The penalty is not only increased labor requirements, but also lower quality consistency.

(continued on pg. 2)

Who We Are and How We Work

The AIM Project is a team of researchers, policy leaders, consultants, and local economic developers working to understand the concrete implications for Michigan of a changing automotive industry. A six-person central research team (CRT) whose work is overseen by an advisory board of top-level industry, labor, and local development representatives sets the research agenda. Working in parallel with the CRT, a database development team coordinates an information-gathering effort involving local economic development agencies around the state. The current CRT and core Project staff includes:

Daniel Luria
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Center for Social and Economic Issues
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David E. Cole
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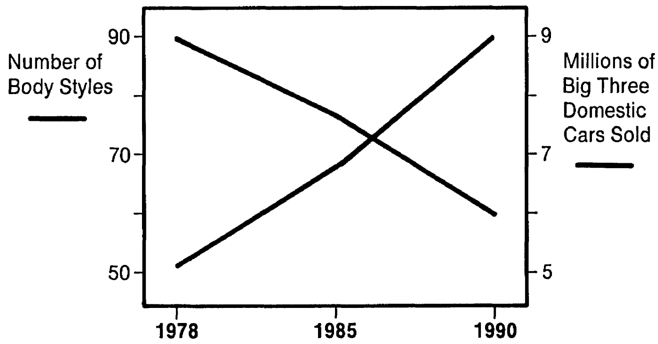
Stamping *(continued from pg. 1)*

Flexibility Demands

The advantage of quick die change is heightened by the sales declines caused by more imports and transplants and by the increasing dispersion of market demand into smaller and smaller body style niches.

Figure 1

Fewer Traditional Domestic Cars Produced, But More Body Styles



That same "nichification" also makes more attractive the reconfiguration of panel stamping capacity to be adjacent to final assembly plants, making quick die change even more essential. With modern stamping presses capable of producing panels as fast as 14 to 16 pieces per minute, sizeable and costly inventories of stamped parts would quickly pile up at final vehicle assembly plants building one car per minute. If such production mismatches are to be avoided, there will have to be at least four die changes per eight-hour shift.

UPDATED RISK RATINGS OF MICHIGAN CAR AND LIGHT TRUCK ASSEMBLY PLANTS, 1986-1992

			Risk factor				
Co.	**Plant**	**Current (1986) Program(s)**	**Age of Program(s)**	**Attributes of Plant**	**Perceived Labor Climate**	**Imports or Out-sourcing**	**Plant Risk Score**
GM	Clark/Fleetwood	B,D	8	8	6	0	22
	Pontiac 1	P	2	2	2	8	14
	Pontiac 8	G	9	4	3	2	19
	Pontiac 5	S10	5	2	4	2	13
	Willow Run	H	0	2	5	2	9
	Buick City	H	0	2	3	2	7
	Lansing	N	1	2	4	7	14
	Orion	C	3	2	8	3	16
	Flint Truck	C/K,K	8	4	8	0	20
	Poletown	E/K	0	2	4	2	8
Ford	Wixom	LS, Panther	7	2	5	0	14
	Wayne (Truck)	Bronco, F	6	2	4	0	12
	Wayne (Car)	Erika	5	2	2	9	18
	Dearborn	Fox	7	5	3	6	21
Chrysler	Jefferson	K,E,CV	8	5	4	4	21
	Sterling	H,P	1	2	4	5	12
	Warren	D/W,N	0	2	5	2	9

(A "Plant Risk Score" of 15 or higher indicates danger.)

Die Costs and Plastics' Threat

In the past, the American vehicle manufacturers have designed their dies for steel parts to comparatively tough and high standards. This was a natural consequence of very long part runs to satisfy high-volume car models. It was not unusual in the 1960s for U.S. automotive manufacturing engineers to ridicule the fragile nature of tooling designed to Japan's relaxed standards; in fact, those standards were quite appropriate for the low production volumes then characteristic of Japanese production.

Additionally, U.S. dies were designed to withstand marginal maintenance practices and operating abuses of the tools in the presses of the captive stamping plants. The net result of these and other factors was that over-designed stamping dies grew to be expensive investments. Now, as the U.S. car companies seriously evaluate the cost differential of producing cars in the United States versus Japan, it has become obvious that the Japanese produce their dies for steel parts at 60 to 65 percent of U.S. costs, and that the decline in typical U.S. parts run length may now justify Japan's kind of dies.

The captive regional stamping plants have almost exclusively produced parts from steel material. With a growing number of body panels and structural members in the early 1990s expected to be produced of plastic materials, another important loss to regional stamping plants will be created. Plastic parts molded in-house by the automakers are likely to be produced adjacent to the final vehicle assembly plant, not in the regional stamping plants. It also appears that the automobile manufacturers will purchase a substantially greater share of plastic body skin parts than they do for steel parts. This will be a significant new business opportunity for independent plastic molders.

WHY PLASTICS?

- Shorter run lengths
- Lower tooling investments
- Quicker to first good part
- Part integration
- Reduced weight
- Corrosion/dent resistance
- Avoid stamping plant "culture"

However, the gain of the plastic molding industry will be a loss to the metal stamping industry, including both the captive regional and the independent plants. The latter are much more heavily represented in Michigan, which produces close to two-thirds of traditional domestics' panels, than are plastics plants.

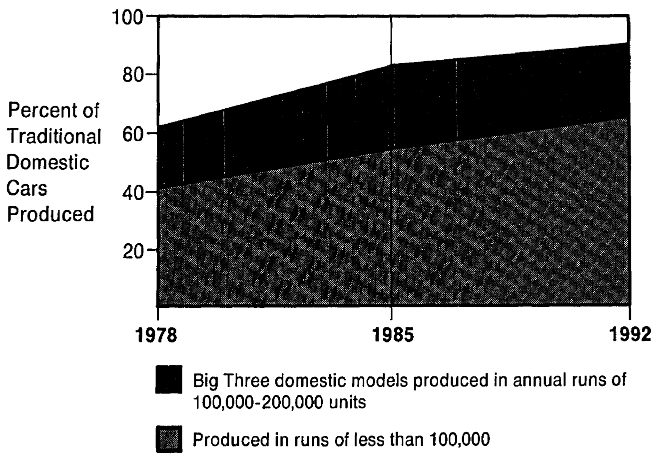
Several factors will influence the material selection for future automotive components. However, one very important one is the relative cost of tooling for stamping dies and the molds for plastic parts. Costly stamping dies create a penalty for steel.

That means fewer dies made in captive plants' tool rooms; and domestic vehicle manufacturers make few of their molds. They buy them mostly from independent moldmaking companies in the United States or in Canada. Independent moldmaking and toolmaking companies often enjoy a 2-to-1 tool manufacturing cost advantage over the captive toolrooms of the vehicle manufacturers' press plants. On this basis, a straight one-mold-for-one-die comparison, the cost to produce a mold in an independent moldmaking company is about 50 to 60 percent of that which domestic vehicle manufacturers require to produce a die in-house.

However, at today's production rates of roughly one plastic part every 2-3 minutes, the productive capacity of a mold is constrained to about 100,000 pieces per year. Thus, if the plastic part is to be assembled on a vehicle with a market potential greater than 100,000 units per year, multiple sets of tooling are required. But, as Figure 2 shows, it seems likely that most models will in the future be made in runs of under 100,000.

Figure 2

Declining Production Levels in Each Body Style

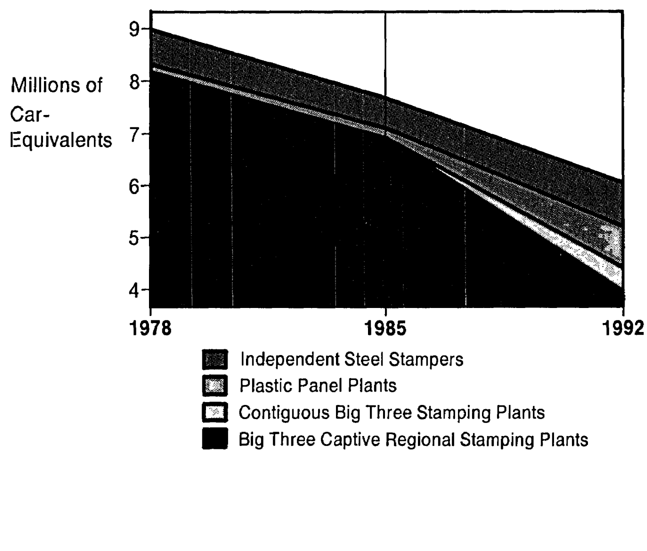


Steel's Fightback and Sourcing Changes

Several developments give reason for cautious optimism, however, about steel panels' prospects. Following Japanese-style designs and practices could cut costs substantially. A promising new mass-casting diemaking technology based on an epoxy resin process could help as well, slowing the decline in business and employment prospects at the captive regional stamping plants.

Figure 3

Sources of Major Body Panels for Big Three Traditional Domestic Cars



Life will change at regional stamping plants that remain open. Buying rather than making at least some of the parts traditionally formed in captive regional stamping plants will accelerate. In the past, the regional stamping plants were often able to compensate for their higher labor and tooling costs by concentrating on extremely high-volume parts. However, with more models of smaller volumes being required in the U.S. marketplace, more stampings are being produced in the shorter runs that play to the independent stampers' quicker die change and labor cost advantages.

More stamped parts will be bought not only from traditional U.S. independent stamping companies, but from foreign-owned stamping companies coming here to serve Japanese assembly plants located in the United States.

Engine Manufacturing Strategies for the 1990s

AIM Analysis by Richard P. Hervey

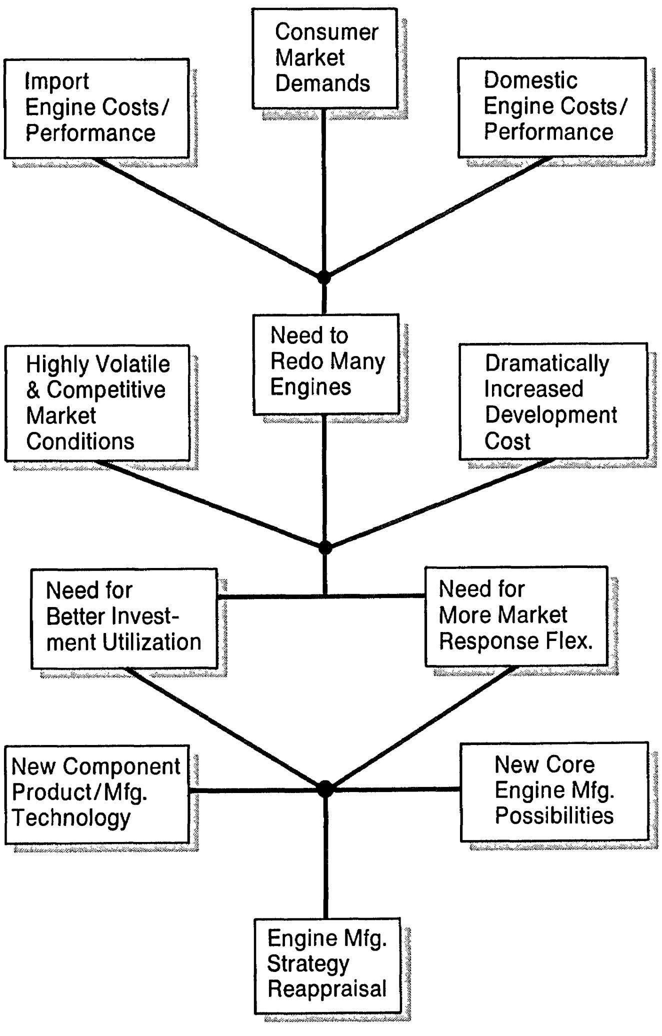
Michigan hosts a disproportionately large share of North American engine and engine related production (65-70%, compared with about 35% of vehicle assembly) and of related machinery and equipment capacity. Hence, Michigan stands to be dramatically affected if anything significant changes in how engines are made.

Introduction

Engines are not simply commodities. Increasingly, they play an active role in the differentiation process, at least with respect to some segments of the market. Thus, they must be managed as a key part of an overall product/market strategy in an excess capacity market.

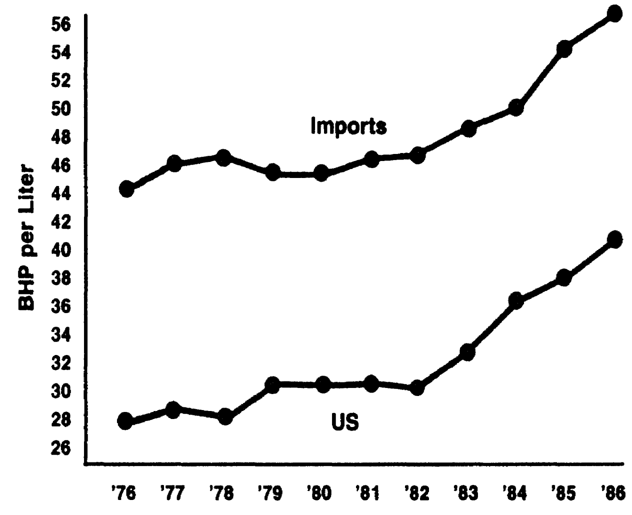
Exhibit 1 shows the resultant decision-making logic. The increasing importance of engine performance in consumer vehicle purchase decisions forces North American automakers to review their "stable" of engines, and to rate them against their Japanese and European competitors. They find in many cases that our "horses" do not measure up in terms of performance/cost/durability. Thus the automakers conclude that a major part of their engine product line must be revamped over the next few years in order to maintain (against the moving target of competitors' engine developments) or regain competitive advantage.

Exhibit 1



In the dog-eat-dog 1986-1995 market environment, capital may get scarcer just as engine development and facilitization is getting dramatically more expensive, as we reach for the refinements demanded by more sophisticated potential buyers. The automakers conclude that they must limit the number of different base engines they develop, maximize investment utilization and yet increase the responsiveness of the engine-making endowment to rapidly changing marketplace needs and desires.

Average Horsepower per Liter



An understanding of these forces causes automakers to recognize that not only must they redesign many of their engines, but at the same time they must totally reappraise their fundamental engine manufacturing strategy. We postulate that automaker managements (and suppliers, labor, local and state governments) are (or should be) asking themselves:

1. What is the optimal engine manufacturing module size? How should this be determined?
2. What components should be made in engine plants? Where and by whom should they be made if not in the engine plant?
3. What product requirements and manufacturing technologies are evolving that might change the answers to the foregoing questions?
4. What strategies most profitably implement the answers?
5. What are the implications of these answers for the constituencies involved? What can be done to smooth the transition?

Optimal Module Size

Neither market volatility nor the need for quick-response flexibility seems consistent with high investment utilization. Exhibit 2 shows the year-to-year volatility in production of engines by General Motors, for example. While the overall engine build declined by about ten percent from 1984 to 1985, production of individual engine product lines grew as much as 29% or shrunk as much as 42%. In fact, the year-to-year individual engine flexibility actually demanded by customers may have been even higher; engine capacity constraints may have meant some lost sales.

Serving the "fickle marketplace" is expensive, though the sales and profit foregone may be even greater if potential customers go elsewhere because they cannot get the vehicle/engine combination they desire.

What about the effect of module size and flexibility? If we assume that GM plans its engine capacity on an average daily production per-module capacity of 1600 (about 400,000 engines per year), then in order to meet 1984 demand it needed 15 modules. However, since modules are not fungible among different engines, GM had to have had a minimum of 18 engine modules operating during 1984. Thus, in 1984, it had no more than 83% capacity utilization, and conceivably less. With the sales decline and product mix changes in 1985, GM engine capacity utilization fell to no more than 76%.

Exhibit 2

Engine Production Volatility (Thousands of Units)

Type	Liters of Displacement	1985	1984	Change
4 cyl.	1.6	175	290	−39.7%
	1.8	161	279	−42.3
	2.0	469	606	−22.6
	2.5	691	537	+28.7
6 cyl.	2.8	616	643	− 4.2
	3.0	341	316	− 7.9
	3.8	682	790	−13.7
	4.1	—	32	NA
	4.3	104	—	NA
8 cyl.	4.1	327	321	+ 1.9
	5.0	1109	1364	−18.7
	5.7	52	47	−10.6
	Totals	4727	5225	− 9.5%

Source: Ward's Automotive Reports

If, however, GM had had engine modules rated at 400 per day, while it would have had to have *more* of these smaller production units, it would have been able (theoretically) to reach 95% capacity utilization in 1984 and 86% in 1985. These smaller modules would have had to be more flexible than the larger ones in order to allow for product mix changes. However, it is unlikely that market shifts would have demanded capacity rebalancing (and hence module flexibility) more frequently than quarterly.

To oversimplify what should be a much more complex calculation, if a 1600 per day module requires an investment of $600 million, because of increased utilization the 400 per day modules could have cost 17% more per unit of annual capacity yet required only the same total investment. In addition, these more flexible smaller modules could have been redeployed to match market demand better, resulting in fewer lost sales and hence in increased profits.

Every capacity planner worth his or her salt knows these matters very well. If there were no penalties to shrinking module size, we would all use a number of modules equal to annual production, each of which had a capacity of one. The real world obviously isn't that way. However, one of our key questions is whether manufacturing technologies have changed or will change such that down-scaling penalties, and hence optimal module size, should change as well.

One school of thought is that engine investment costs are such that *larger*, but somewhat more flexible, modules are indicated. Another camp feels that flexible manufacturing technology and cost are progressing at such a rate that there will soon be few or no penalties to using many small, highly flexible engine production modules. Both groups envision using CNC and DNC concepts (including higher-level supervision of the factory equipment), but are implementing these concepts in very different ways.

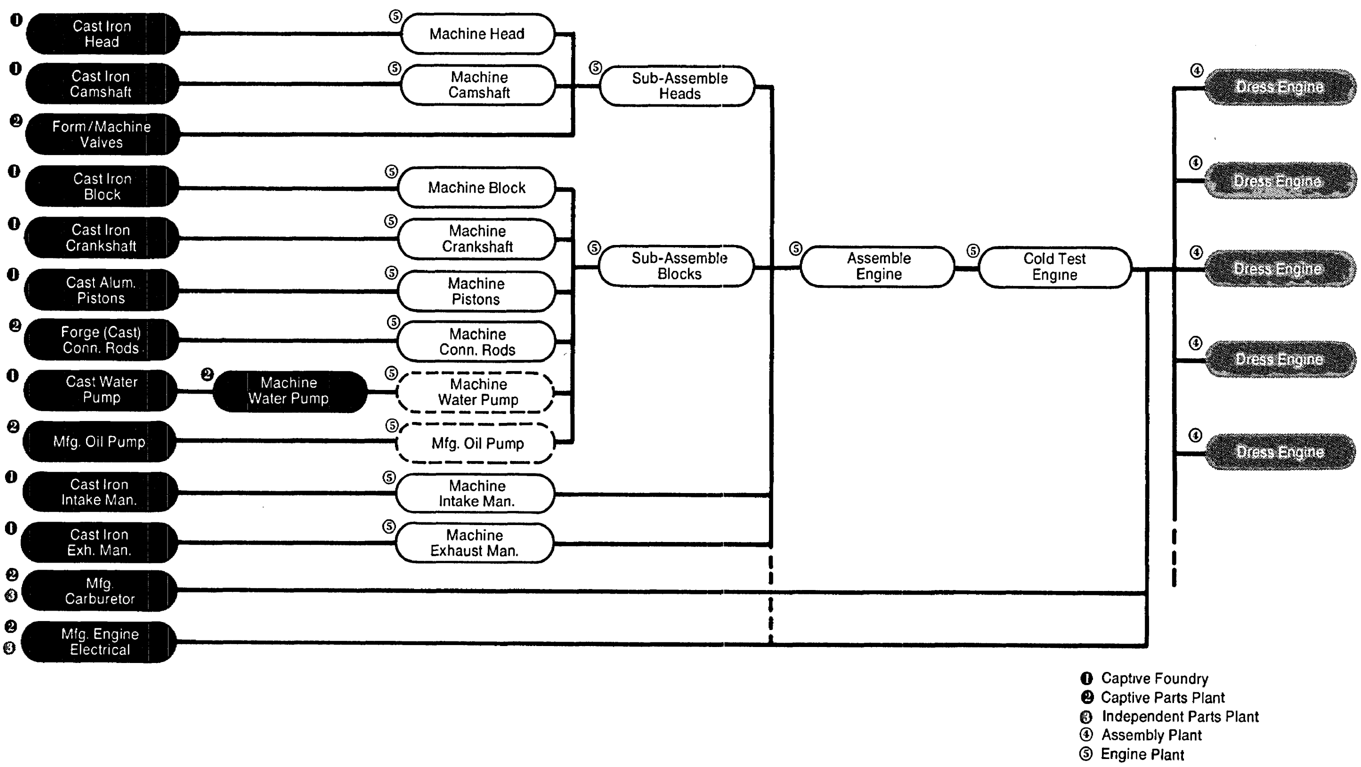
We are hardly expert enough to appraise the technical/economic wisdom of these two extremes (let alone all of the combinations between them), especially without proprietary operating data and estimates. However, we will try to describe how these different views might play out.

Manufacturing Content in the Engine Plant

We now turn to the engine plant itself to discuss what is actually manufactured within it. Traditionally, engine plants made as many as possible of the components which went into the engine; until surprisingly recently, one just couldn't be sure enough of outside machined parts' and assembly components' dimensions, properties, and performance. On the other hand, if the part was cast or forged or stamped or molded, it was bought by the engine plant, often from captive operations within the same automaker. This situation is pictured in (the inevitably stylized) Exhibit 3.

Exhibit 3

"Classical" Engine Build (late 1960's)



Note that many components, central and peripheral, were made within the engine plant itself, normally of raw castings, forgings, etc. made in captive foundries and forges. This was not surprising as making an engine is a high precision process which, at the time, required such integrative functions as selective assembly. This meant, however, that when a new engine plant was required, it had to be sized with all of the peripheral machining/subassembly included. This also required that engine plant personnel be expert in the machining and assembly of many different types and sizes of parts designed for and made from quite diverse materials.

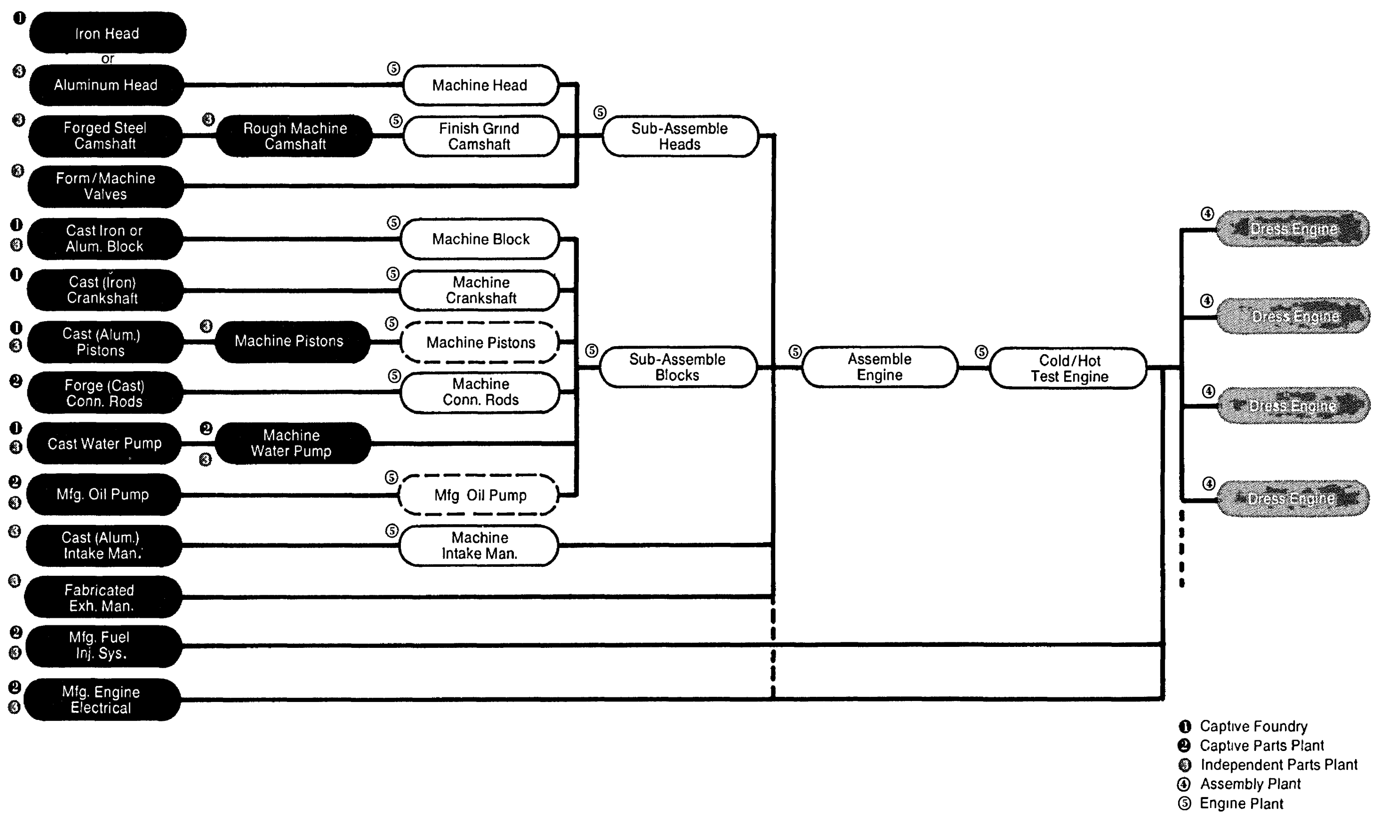
But as early as 1970, some of the manufacturing content was being removed from the engine plant. As emission control regulation came into force and engine manufacturing became more complex (often requiring more floor space), water pumps and oil pumps were moved outside the engine plant, usually to captive parts machining plants. This trend has continued, until today (Exhibit 4) most of the content at the "front end" (first column) is performed outside the engine plant.

Engine component design and materials selection are becoming more demanding, often requiring more specialized facilities. For example, camshafts are moving from iron to steel as roller lifters are introduced to lower engine friction. There are various ways (being tried) to manufacture these more difficult camshafts. However, they all share the characteristic that the highest quality, lowest cost way to make them requires integrated process control and optimization among several trades (e.g., forging and machining).

The techniques of processing these high-tech engine components are often so specialized that they are best developed and implemented by experts, who can then prorate the development cost and specialized facility investment over several automaker customers. On average, these products/processes are simply more important to these specialty firms than they are to the big automakers.

Exhibit 4

Current Typical Engine Build (mid-1980's)



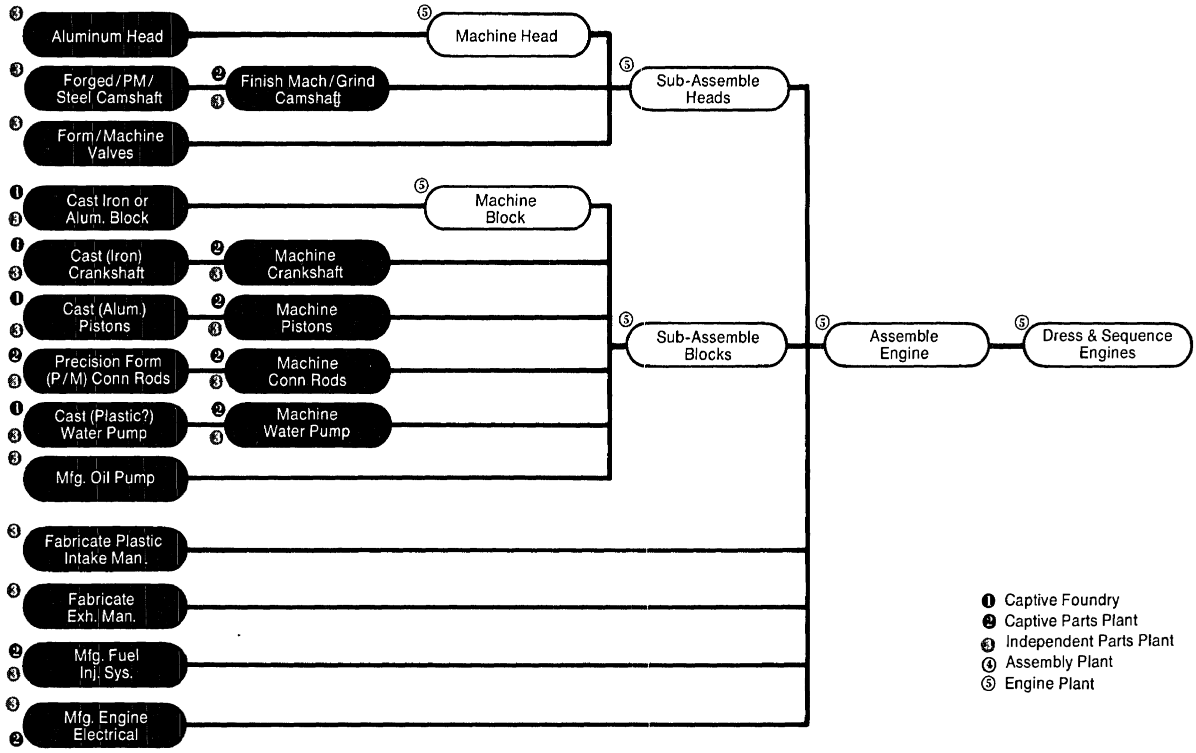
And, more of this component manufacturing is being done outside the automaker itself. In part, this came from the introduction of new materials, designs, and production technology, the capability for which was stronger in firms specialized in making that particular component for several customers. However, in part it came from the realization by automakers that the cost of outsourced engine parts was lower than that of captive foundries and machining plants. This cost savings derives partially from the lower labor cost and overhead outside the Big Three, and partially from the aforementioned economies of specialization. These outside operations were often organized on a product line basis rather than a trade or process basis, for example, casting and machining pistons rather than casting or machining many diverse parts (see box).

We predict this tendency will accelerate as the next generation of engine technology is facilitized. In Exhibit 5's future engine plant, only core (usually large) components are machined in the engine plant. Both technology and the application of statistical process control now allow far more interchangeability of parts and the elimination of selective assembly. Beyond the physical aspects, SPC gives the engine plant manager confidence that outside suppliers will make reliably good parts.

We see in this an emerging trend by automakers to consider outsourcing anything that they can outsource without sacrificing world-class quality. Moreover, a significant part of this outsourcing, although by no means all of it, will be placed with foreign firms, many of them European, with some losses for Michigan workers and communities.

Exhibit 5

Possible Future Engine Build



Some of these specialized foreign engine parts manufacturers have already built manufacturing facilities in the U.S., and with recent currency realignments, more may. Obviously, this is an opportunity Michigan does not ignore.

In sum, the future engine plant will have fewer different operations. It will focus on making fewer parts better and on developing flexible assembly systems allowing rapid, low-cost response to changing customer needs. It will optimize the core (head and block) engine-making process while counting on outsiders to optimize the manufacture of other components. The alternative would be for engine plant management to sub-optimize more of the engine content, something already perceived as having put them at a competitive disadvantage vis-à-vis Japan and Europe.

Alternative Models

Several elements must now be integrated. The removal of certain manufacturing operations from the engine plant seems clearly under way, particularly with fundamentally new engines. On the other hand, there is still great uncertainty as to whether the ideal module size is growing (Exhibit 6) or shrinking (Exhibit 7).

The "Focused Concentration" of Exhibit 6 assumes that the technology/economics of engine building is evolving such that closely related engines should be manufactured and assembled in large plants serving all of the assembly plants using that engine. Each of these plants might be flexible enough to make variants of the same basic engine (as is often the case today) or even somewhat different engines.

Depending on the engine mix needs of the automaker, these plants might become larger (in terms of capacity). They would be far more flexible than today's engine plants, which might require some compromise in engine design and certainly in processing optimization.

The "Contiguous Manufacturing" of Exhibit 7 follows concepts of Just in Time. Here it is assumed that the incremental costs of many small engine-building modules, each set up to serve one or at most a few selected assembly plants, is outweighed by lower minimized inventory cost and the customer responsiveness associated with engine plant management identifying more closely with "their" assembly plant's vehicle requirements in the market.

These small modules would have to be quite flexible, although perhaps less than one might think: the investment/operating penalties involved might well be quite small. Although the basic concept would be to serve one assembly plant with one or more engine modules, one would want to provide for interplant shipping as well, as shown in Exhibit 7 where Engine Module C-1 serves Assembly Plant B as well as C.

Presumably, the choice of one or the other of these strategies is dependent on an appraisal of the specific automaker's vehicle/engine mix and of the investment/operating cost penalties implied by the smaller modules.

Clearly there also is room for a mixed strategy, in which large "base load" plants might be supplemented by smaller "swing" engine plants that provide the necessary flex for the entire engine supply base. We assume that this approach might be taken if a manufacturer feels that the penalties of small modules are still too large yet large plants still too inflexible. Once again, forecasted engine/vehicle mix will be a key decision determinant.

Implications for Automakers, Labor and Suppliers

The configuration and certainly the location of the engine component-making infrastructure almost certainly depends on which strategy is chosen by the automakers. If there are fewer, somewhat clustered engine plants as the "Focused Concentration" model implies, one can anticipate fewer, somewhat clustered parts plants. The "Contiguous Manufacturing" model could (though would not have to) imply the opposite.

Either way, there will be major impacts on the constituencies interested in engine and vehicle building in North America. Even a "No Change" engine manufacturing scenario would have major impacts: if change is necessary to properly serve changing consumer desires, "No Change" would mean more loss of market share; that may make it the alternative with the highest risk to all. It must be emphasized that different strategies will be appropriate for each of the Big Three, depending on each firm's current engine-building endowment, likely future market position, and capital/human resource base.

Exhibit 6

Focused Concentration Model

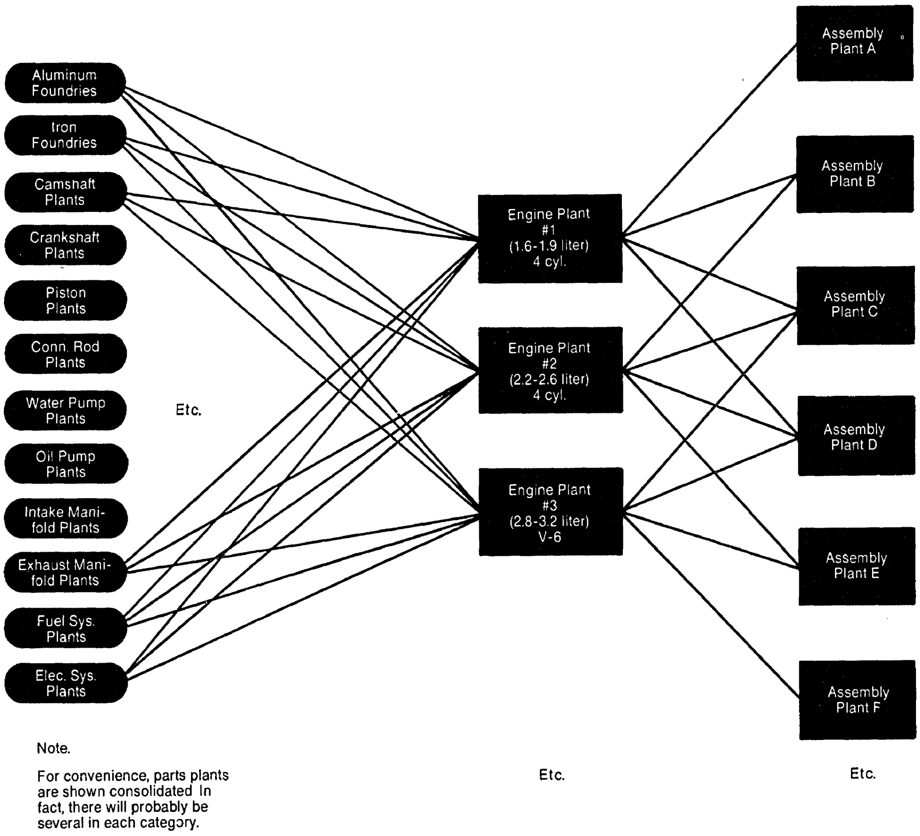
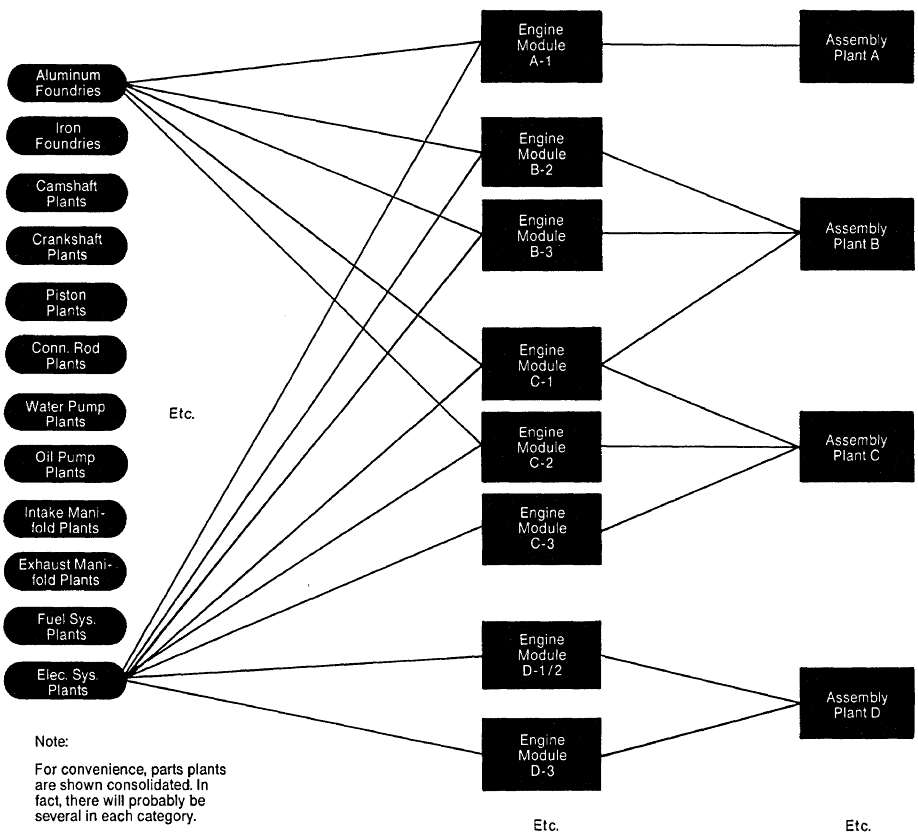


Exhibit 7

Contiguous Manufacturing Model



The potential impact on labor is enormous in every one of these manufacturing strategies. Although engine manufacturing itself is not as labor-intensive as most other parts of car building, increased productivity will inevitably mean job loss. And, engine plants may be located in different places than today. More important, engine parts outsourcing to non-Big Three plants will mean a different split of union/nonunion and UAW/non-UAW. Even a transfer of work from engine plants to captive parts plants usually means that different workers are employed, and there is a significant question whether many engine parts can be profitably resourced to captive parts plants.

For the work which remains in engine plants, capital utilization will become a much more vital element in the profitable operation of the plant. This may require changes in work rules in existing plants to dissuade management from preferring new plants with more "cooperative" workforces. Skill levels of remaining jobs will almost certainly increase. The ability and willingness of work crews to keep their equipment working with minimum delay will be vital.

Suppliers will also be impacted greatly. For independent suppliers, significant business opportunities will be presented. The choice of suppliers will depend in large part on which step up soonest and best to the increasingly complex (and, probably, capital intensive) task of managing a vertically integrated supply of a whole "function" within an engine.

Captive suppliers (and non-vertically integrated lower level independents as well) face a particularly difficult challenge. They have both offensive opportunities and defensive risks. A captive foundry, for example, will probably have less chance of capturing an independent machining company's business than a sister engine plant's. In fact, even captive upstream parts plants may increasingly have to look to independent castings and forgings suppliers if they are to remain competitive. Thus, we think that the least upstream captive plants (foundries and forges) are in the worst position.

The choice of Focused Concentration or Contiguous Manufacturing may affect different suppliers in different ways. All things being equal, we think the former favors captive suppliers, while the opposite is true in the latter.

Finally, there will be impacts on engine machinery suppliers, especially those that make both machining and assembly equipment. To the extent that engine parts are outsourced to non-captive suppliers (even if manufacturing in the U.S.), machinery-buying is likely to favor foreign firms. Machine tool suppliers will have to identify those firms and change their product lines and marketing approaches to serve them.

The portion of the work that remains within the automaker, even within the engine plant, will also pose serious challenges to machine tool makers. The needs for flexibility implied by either strategy require considerably different equipment than has historically been supplied by the Big Three's traditional machine tool suppliers.