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The Future of Modular Automotive Systems: Where are the Economic Efficiencies in the Modular-Assembly Concept?

by

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Office for the Study of Automotive Transportation
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Introduction

The world auto industry has experienced many fundamental changes in its long history. The majority of these changes have involved important shifts in the market for motor vehicles or improvements in product or manufacturing technologies. Automotive firms have usually responded to change by developing strategies designed to preserve or even to improve efficiency. In particular, several of the most critical decisions made by motor-vehicle firms concern the integration levels of the firm in vehicle manufacturing and customer sales.

For many years, a standard pattern practiced by vehicle firms was massive integration and heavy capital investment in manufacturing the vehicle and its components. On the other hand, vehicle firms appeared to be very willing to assign almost all of the direct contact with vehicle buyers to independently owned and operated dealerships. In recent years, however, the standard upstream integration paradigm has been called into question. In particular, a great deal of discussion—and industry planning—has centered on the potential future of the use of modules in design and production of motor vehicles.

This report investigates some of the issues raised by the increasing use of modules, or "modularity," in vehicle assembly. The issues we are most concerned with are ones that are of the greatest interest to the members of the Michigan Automotive Partnership (MAP) and the state of Michigan's economic development organization, the Michigan Economic Development Corporation (MEDC). This report, however, will concentrate entirely on one of two recognized types of modularity. We initially define these two categories as follows:

(1) Level-one, or assembly, modules. These include the assembly of component sets that are not optimized by suppliers at the final assembly level. In other words, the practice of shifting subassembly lines that manufacture modules next to the final vehicle assembly line to separate supplier facilities at some distance from the plant. No fundamental change in design or content of the module is effected in these cases.

(2) Level-two, or design, modules. Modules that are optimized at the final assembly level by independent suppliers.

The supplier survey reviewed in this report will restrict itself to an investigation of only level-two, or design, modules. We made this decision because level-one modularity, by its very nature, provides little potential for improvement in vehicle cost or design. Level-one modularity merely represents another form of outsourcing usually for the purpose of reducing labor costs. Level-two modularity, however, carries the promise of a far greater range of system-wide improvements in design, materials use, rates of product innovation, delivery time to market, and cost.

Four major issues stand out in importance for the sponsors of this report:

1. To what extent are modules used in vehicle manufacturing today? What is the likely use of modules by vehicle type in the near future? Which areas of the vehicle will first experience increasing modularity in the future? Finally, what does the use of design modules imply for the final structure of the supplier industry in North America?
2. A major driver of the use of modules is their potential to reduce costs in component and vehicle assembly manufacturing. What is a reasonable estimate of the cost impact of the use of modules? Does this vary by type of module? What are the major sources of the cost reductions associated with the use of modules?
3. What are the economic-development implications of the use of modules? At what distance will modular supplier assembly facilities be located from customer assembly plants? Will module suppliers generally be required to build new facilities? What are the employment implications for Michigan?

4. Finally, what changes in the manufacturer/supplier relationship are necessary to facilitate the adoption of system-optimized modules? What barriers or drivers will play a role in the gradual implementation of modularity?

Our major sources of information for this report include valuable information from one major, Detroit-based, vehicle manufacturer and the results of a special survey of the largest automotive suppliers in North America—the module producers themselves.

The Economic Logic of Modularity

Many definitions of modularity in manufacturing are available from many sources. One recent description of modularity in the academic business literature reads as follows:

> *When the components or elements of a product or process can be made independently in different organizations and then assembled by a system integrator with predictable effect.*[1]

Inherent in this definition is the assumption that the modules (elements or components) represent a significant share of the final product value. Also it is assumed that module producers are largely responsible for the design of their products and that a commonly recognized interface exists for incorporating the module, with some modification, into final products assembled by separate customers.

The use of preassembled modules in producing final products, of course, is not a new idea. In fact, this production paradigm may have dominated the early history of the U.S. auto industry through 1930. Many of the most important components (especially bodies) of vehicles produced in the 1910-to-1925 period were actually supplied to the automakers by large independent suppliers. Sufficient scale economies and access to capital were not available to the automotive firms during this early development of the market. Of course, the story of integration at Ford and General Motor is well known. Mr. Ford built new component capacity inside Ford Motor Company, while GM completed its process of purchasing many of its largest suppliers by 1930.[2] A major question today, however, is whether sufficient scale economies and adequate capital still exist in order to maintain vehicle firm integration. A related question is whether vehicle firms possess the management and engineering focus to sustain the commitment to component design and manufacturing.

The use of modularity is widespread in today's world economy. Manufacturing industries including shipbuilding, large trucks, commercial and military aircraft, consumer electronics and, of course, computer equipment and related peripherals rely heavily (even entirely) on major supplier modules in the production of final products. The service sector also practices modularity in industries as varied as mortgage lending and software. In the majority of these industries, module suppliers are given complete design freedom except for the necessity of accomplishing certain functional specifications and the task of matching standardized interfaces with other modules of the final product.

The economic benefits of the use of supplier modules are complex and not always transparent. Several recent academic authors have categorized these benefits into three major areas. The first two types of benefits are intrinsically linked to efficiencies in product design and development and the last to cost:[3]

1) **Flexibility**. Vehicle firms that have access to a wide variety of supplier modules will improve their ability to meet changing customer demands because product differences can now be more easily incorporated in the vehicle's final design. Since independent suppliers in each system area can concentrate entirely on internal innovation, the rate of technical change should increase without any loss of previous design capability. Vehicle firms can pick and choose from a wider variety of modules with different characteristics. The expansion of choice should improve the vehicle firm's ability to serve a wider variety of customers.

2) **Speed and Expanded Design Capability**. The use of modules should drastically shorten the time to piece together new products. Vehicle firms merely have to select the correct modules in response to customer functional specifications. This opportunity should be compared with the alternative of long, internal rates of product development hamstrung by different rates of improvement in many system areas. In fact, it is likely that integrated vehicle firms were competitive in only a few systems, and were restricted by their least competent system area in terms of time needed to produce the overall product. Vehicle firms that make heavy use of modularity in design will be free of the encumbrance of developing competencies in many arcane

manufacturing and engineering areas of expertise. Instead, these firms will be able to specialize in the optimal use of modules in vehicle design. This specialization implies optimization at the functional or consumer level. Indeed, such firms will devote a larger portion of their resources to the final product market—even at the retail level.

3) **Reduced Cost**. This benefit of modularity has received more attention and has generated more discussion (especially by auto analysts) than the other two benefits. The other two benefits, of course, also imply a reduction in product development cost, but also offer the potential of increased revenue through improved product alternatives. All in all, however, the cost effects of modularity can be grouped into three broad, somewhat interdependent areas:

a. Labor costs

Wages: The major impetus for return to use of level-one, or assembly, modules are cost reductions due to substitution of lower wage rates paid by suppliers versus union-bargained rates at vehicle assembly plants. Many analysts perceive this as a short-term return, which can be accepted only once. Yet the gap between nonunion supplier wages and vehicle-firm hourly rates is very large and has shown no recent downward trend. An OSAT survey of 140 suppliers in the summer of 1998 measured a wage premium of almost 95 percent for union labor cost in vehicle-firm manufacturing versus labor rates at nonunion supplier plants. In fact, the gap between union supplier wages and vehicle-firm rates was still on the order of 60 percent (see table 1). This return is also available, of course, in the case of level-two modularity.

Labor productivity: Many module suppliers can specialize to a greater degree in the manufacture of their particular product than any vehicle manufacturer. Suppliers therefore can often build more efficiently designed facilities and equipment, organized at a greater level of optimization, than the subassembly lines contained within vehicle plants. This can result in both higher labor and higher capital productivity. Higher supplier productivity is especially likely if suppliers learn faster about the best ways to manufacture their modules than do individual assembly plants.

Table 1
Automotive Manufacturing Wages

	1998 Wages
Union Supplier	
Trades	$15.10
Other Production	13.00
Non-union Suppliers	
Trades	$16.41
Other Production	10.06
Big "3"	
Trades	$23.50
Other Production	19.55

Source: Michigan Automotive Policy Survey, UMTRI-99-1

b. Engineering efficiency

Reduced engineering effort: A major benefit of level-two system modularity is purported to be increased efficiency in component and vehicle design engineering. The outsourcing of many parts to independent suppliers, of course, has long been a feature of automotive manufacturing. Much of past sourcing of parts and component work to independent suppliers was motivated in the past by lower labor costs in the supplier sector. However, suppliers were rarely granted conceptual freedom in the design of their products. Instead, a layer of "release" or "detail" engineers are employed by the vehicle firms for the purpose of ensuring not only functional but also dimensional, system, and cost standards for supplier parts in the overall vehicle. The cost of "ghost" engineering needed to effect the integration of parts from many different suppliers is apparently enormous in terms of not only engineering hours, but also delays in the product development process.

The eventual reduction in engineering effort through the use of modules can be illustrated in two dimensions in figure 1. Suppose a "chunk" of the vehicle or one of its systems is composed of 16 individual parts as shown in figure 1. The chunk would contain no fewer than 24 internal "interfaces" between the parts. These interfaces are areas of great concern to many release engineers, since the parts must fit and even operate together in a functional way. Considerable ghost engineering would be expended at the vehicle firm if the 16 parts were supplied by 16 independent companies. The number of interfaces would fall to only four, if, however, the large chunk of 16 parts was reduced to four smaller chunks of four parts each as shown in figure 1. In other words, the level of ghost engineering would fall by five-sixths if the parts were bundled into modules. Since the 16 original parts were already outsourced, the new module arrangement only represents more efficient outsourcing. Finally, if the module suppliers themselves outsource their parts and are forced to practice ghost engineering, the gain in engineering efficiency disappears. Modularity must be practiced throughout the entire supplier chain to realize gains in engineering efficiency.

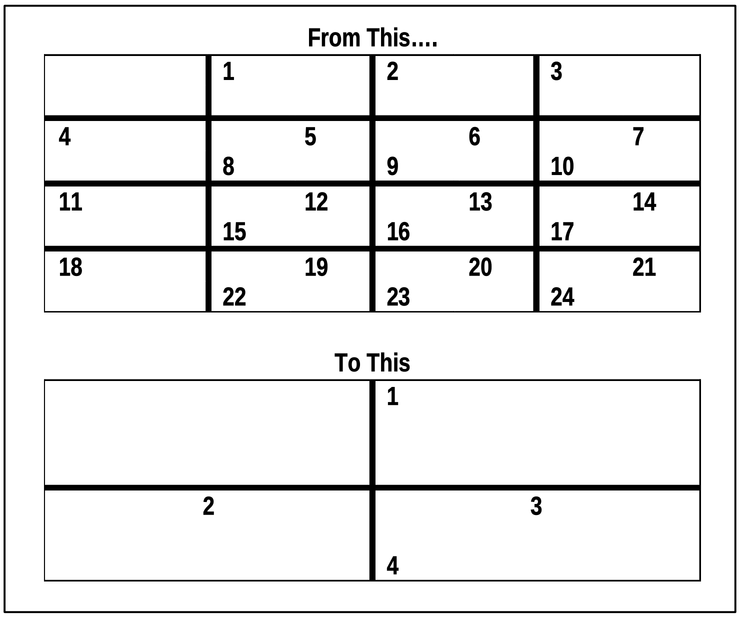

Figure 1
Fewer Interfaces

Materials cost reduction: Closely related to the possible increase in engineering efficiency from the use of modules is the further potential to reduce material costs and even weight in the overall vehicle. It is apparently true that parts made by different suppliers contain additional material to ensure their integration into larger chunks within the vehicle. Once again, the additional materials cost is related to the number of interfaces between parts. Assigning the responsibility of producing modules of interrelated parts or components to the same supplier, however, creates the design freedom to save on materials and even allows for the elimination of unnecessary parts altogether. This is true because the entire module is now engineered or optimized as a whole rather than separately part by part. Finally, the shifting of responsibility for module design to the suppliers allows the vehicle firm to concentrate on design for assembly at the macro level, or at the outside interfaces of modules. The detailed concern of vehicle engineers is reduced from thousands of parts and components to perhaps only two or three dozen modules in final assembly.

c. Scale economies and lower investment

An important cost benefit arising from the use of modules is lower plant and equipment investment for vehicle firms. Since the bulk of subassembly lines and not a small amount of work from stamping plants and assembly body shops are performed by suppliers with use of modules, the gross investment savings for vehicle firms would appear to be immense. Yet suppliers will need to increase their investment in replacement lines at their own facilities if modules are to be produced. An investment by suppliers equivalent to that once made by vehicle producers would, of course, result in no net gain in terms of fixed costs. The current argument, however, is that suppliers will invest less than vehicle firms once did because they will design more efficient production lines, or because they will supply more than one customer with standardized component modules from each facility.

Modularity and the Restructuring of the Auto Parts Sector

Will the use of large modules create a new tier of super system suppliers? The hierarchy shown in figure 2 is suggested by industry observer Joseph Day of Freudenberg-NOK.[4] The taxonomy shown in figure 1 contains four tiers. The fourth tier, or 2.0 suppliers, is made up of simple parts producers who may or may not possess special manufacturing process skills. The third tier, or 1.5 suppliers, contains companies who produce functional components such as compressors or gaskets that must operate to precise specifications within a larger system that interacts with the vehicle buyer or plays a major role in vehicle performance. Functional systems are produced by the advanced, first-tier system suppliers. Finally, a new super system level of supplier actually combines separate systems into modules. These suppliers have been recently tagged as ".5" suppliers to separate them from the old definition of first-tier systems suppliers ("1.0" suppliers). For example, a .5 integrated system supplier might have the capacity to produce the entire interior of the vehicle including the cockpit with HVAC (heating, ventilation, and air conditioning).

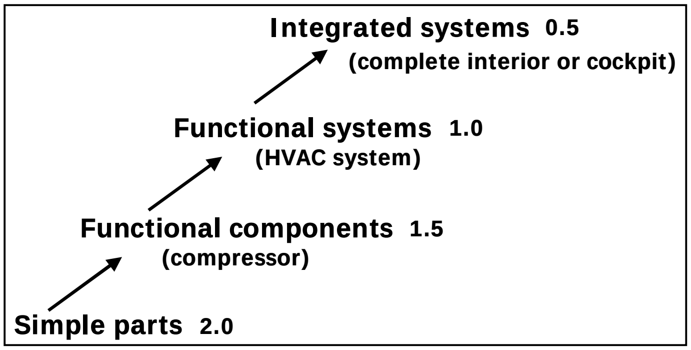

Figure 2
Hierarchy of Supply?

Criticism of Automotive Modularity

Some criticism has surfaced regarding the logic and practicality of module assembly. Clearly the strongest complaints have emanated from the United Autoworkers Union (UAW) who are naturally concerned about membership losses at their assembly plant locals. On the other hand, several well-known automotive consultants have also expressed concern at the rapid acceptance of an unproven design and production system by many of the major automotive firms. In particular, Richard Hervey of Sigma Associates has recently voiced several concerns regarding the engineering and business feasibility of the use of modules in motor vehicles.[5]

Hervey draws from the work of Ulrich and Eppinger[6] for his theoretical approach to automotive modularity. These two authors define two types of product architectures. The first is “modular architecture where chunks implement one or a few functional elements in their entirety and the interactions between chunks are well defined and are generally fundamental to primary functions of the product.” The desktop PC, containing an overarching “operating system” is a prime example of modular architecture. It should also be noted that the PC system modules share a common power source, electrical. The second type is integral architecture “where functional elements of the product are implemented using more than one chunk, a single chunk implements many fundamental elements, and the interactions between chunks are ill-defined and may be incidental to the primary function of the product.” Hervey defines the automobile “as an outstanding example of integral architecture.” It should be noted that the major systems of the automobile do not share a common direct power source. Some systems rely on hydraulic power, some on electric, some use electromechanical, and some use multiple power sources.

Hervey's point is that the physical architecture of the vehicle or the module chunk does not necessarily match the distribution of systems in the vehicle. Many vehicle systems are located throughout the vehicle. For example, suspension and braking is located at each corner of the vehicle in addition to the engine compartment and vehicle interior. Another example is the front-end module, which may contain elements of three separate, not closely related vehicle systems (engine cooling, electrical, and safety). Therefore, the module supplier may find it almost impossible to cross-optimize the physical module and only partial elements of three systems. The job of cross optimization has been traditionally performed by vehicle firms in the past. Hervey implies, then, that two requirements of level-two, system modularity, the existence of known, standardized interfaces, and the ability to optimize at the complete module are not usually present in the case of motor vehicles.

Hervey also worries about the implied transfer of responsibility for capital investment and therefore of risk to the supplier sector. A switch to modular sourcing by the majority of automotive firms would call for a massive restructuring of the pattern of investment in the world auto industry. Product development and manufacturing activities once largely performed by vehicle manufacturers would become the principal responsibility of independent suppliers who may or may not receive sufficient guarantees of return. The point is not whether suppliers are confident in assurances of financial returns from their customers for the unprecedented supplier investment in competence and capacity. Far more important, it would seem, is whether capital markets would demonstrate such confidence and provide sufficient capital to get the job done (throughout the entire supplier chain). Hervey has stated, "Capital markets will demand demonstration of financial success from limited modular ventures before supporting the concept generally. From what we can see so far, the case has not yet been made to the satisfaction of capital markets. Indeed many module suppliers are still wondering about the concrete reality of modular profits."

The UAW's concerns about modularity are far more explicit. In a recent speech before the UAW's 1999 Bargaining Convention, the union president was reported as stating that "modularity is just another word for outsourcing." Indeed, the most radical modular assembly designs call for the complete elimination of all subassembly or "build-up" lines in the traditional chassis and trim departments of UAW-represented assembly plants. This pattern of outsourcing would call for the transfer of thousands of union jobs to the supplier sector. This transfer would involve jobs that have been negotiated by the union in many plants for over sixty years. No guarantees have been made that the transferred jobs would remain in the union. The union also expresses other concerns regarding the business efficiency of a modular approach to automotive manufacturing:

> But while GM and other automakers claim this approach will lower costs and increase flexibility, just the opposite will result if modular assembly boils down to an extension of the low-road strategy of outsourcing work to lower-wage nonunion suppliers. Less control over design, engineering, production processes and quality on one hand, and increased logistical complexity, freight charges and warranty costs on the other could well make modular assembly a costly path for the automakers.[7]

A final point made by some leaders of the union concedes the possibility of potential design efficiencies to the module suppliers. "If suppliers are better at integrating parts and systems of vehicles into large modules, let them do so, and let us still build the modules they design." In many cases, of course, this may actually occur in practice.

Finally, several automotive consultants, such as Sandy Munro, have pointed out the potential of significant pitfalls for suppliers of large modules. Tier-one suppliers of modules may run significant risks of major losses due to major recalls of modules on which they are exposed to total warranty liability. Suppliers are also heavily exposed if a major module program, with significant sunk engineering costs, is suddenly cancelled by customers.

A Modularity Briefing

Several members of the research staff of the Office for the Study of Automotive Transportation (OSAT), attended a special briefing given by a modularity planning team for a major Detroit automaker in early February 1999. The briefing consisted largely of the same presentation on proposed modular assembly plants given to the company's Board of Directors only several weeks before. The major difference was that OSAT would be shown much of the detail the board did not have time to receive. The briefing consisted of a general introduction followed by a series of focused presentations given by the separate area planning managers in charge of product engineering, purchasing management, body shop operations, paint shop operations, general assembly, and facilities planning.

The proposed modular assembly plants were developed during the course of planning of a new compact car platform. The company concluded that its slow approach to "lean," during the 1990s, "hasn't worked," since large net losses in small car manufacturing in the 1990s have been only marginally reduced by traditional efforts.

The modular team's proposal was for a $1 billion investment in U.S. assembly operations that were to be radically redesigned on the basis of presumed learning from the development of a Brazilian project for modular assembly. It was recognized that the essential challenge was to take $1,000 to 2,000 of per-vehicle out of the total cost of small car production in the United States. This would indeed allow the company to make a profit for the first time in many years – perhaps ever – on small car sales. The Brazilian project was to be used as a "consultative benchmark."

The two facilities proposed would each produce 215,000 vehicles annually. The new plants are to incorporate a number of changes from traditional assembly plants that drastically reduce required investment. For example, the proposed modular plants would be able to handle no more than three body styles on a maximum of two vehicle platforms. At the same time, the number of major suppliers to the body shop is to be culled from a current standard number of 23 to no more than 12. Body shop capacity is limited to no more than 45 to 50 jobs per hour and a change of work every two hours. The two plants are connected to two small contiguous stamping facilities. In other words, the traditional large centralized stamping plants that typically feed the company's assembly plants would be replaced by two small press plants employing fewer than one hundred workers each. Finally, the paint shops are restricted to no more than eight paint colors and no two-tone paint jobs. The paint shop investment is a very low figure for typical U.S. operations. The low investment cost is largely accomplished by restricting maximum capacity to 45 to 50 jobs per hour.

The role of modular sourcing is clearest in the trim and chassis sections of the plants. A total of 137 workstations are planned for these departments. Thirty-five module delivery doors are located around the perimeter of this cross-shaped section of the plants. Only 32 part numbers or modules are to be delivered to the trim and chassis departments, from a net total of 13 modular suppliers, through these doors. Line speed is to be set at no higher than 38 to 40 cars per hour. The plant is to be run normally at three eight-hour shifts per day, five days per week, with major maintenance on the weekends.

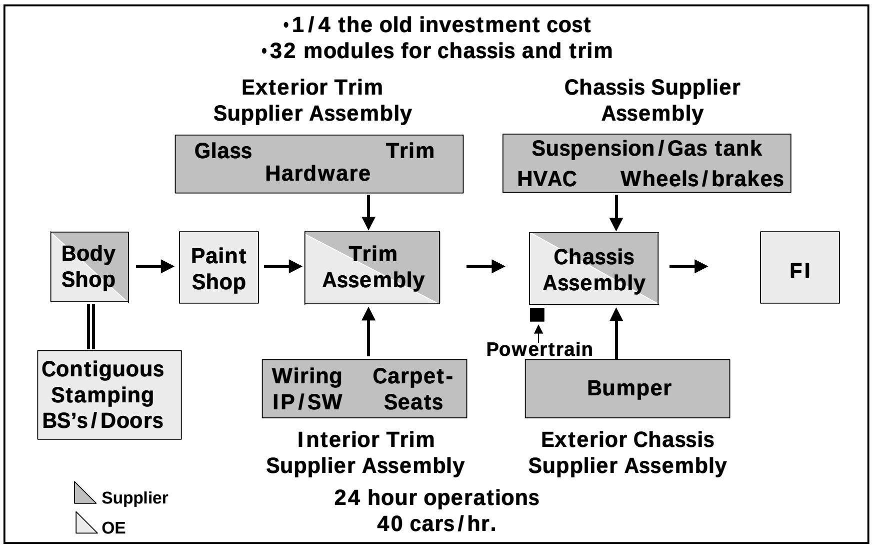

Figure 3
A Modular World in Assembly?

The team stressed the important role of the modular suppliers to the modular project. The following points were highlighted in regards to product engineering:

- The major thrust of product engineering is modularity with full codesign: codesigning with the module suppliers.
- A large number of subsystem components are typically combined in one part number. In fact, all of trim and chassis would have only 32 parts numbers or modules. The majority of current body-shop subassembly lines are outsourced.
- The average number of pages for a statement of requirements (SOR) for the modules is 14 pages of nonrestrictive specifications. This compares to an average best order practice (BOP) SOR length of 200 pages today (a lean SOR is necessary to start the process with significantly reduced specifications).
- Suppliers are fully involved at the styling phase.
- Suppliers are fully responsible for validation.
- Suppliers are 100 percent responsible for warranty costs on modules.

The purchasing planner on the modular team summarized the purchasing process further by describing the request for quotes (RFQ) meeting for the project. At this meeting, potential module suppliers were told that the “affordable cost target” was sacred. In other words, a form of “target pricing or costing” was to be used for the project. Yet concepts were left totally open for the first time in the company’s purchasing history. For the first time, indeed, suppliers could select their own fasteners for use within the module. Modules were to be supplied by region, but the designs are meant to be global. However, proximity in sourcing to the modular plants must be guaranteed. Supplier module plants must be no further than 90 minutes in broadcast distance (in reaction to an order change by phone) from the assembly plants.

OSAT asked how the modular team knew it could accomplish the projected cost reductions. The answer apparently, was simple. The vehicle was “100 percent sourced.” In other words, all the modular parts contracts were signed and in hand, and the prices were guaranteed for the current life cycle of the product.

The purchasing planner on the modular team displayed a telling example of the potential improvements arising from level-two modularity in a comparative sourcing table for the vehicle cockpit:

Table 2
Cost Comparison of Traditional Design Cockpit to Modular Alternative

	Traditional Concept	**Modular Alternative**
Part Numbers	104	1
Assembly Time	22.4 min.	3.3 min.
Mass	63 Kg.	56 Kg.
Material Cost Change	—	-$35
Total Cost Reduction	Baseline	-$79

This table identifies a $79 reduction in the original baseline cost for this installed section of the vehicle. Almost half of the cost reduction is in the form of reduced material costs (44 percent). The reduced assembly time amounts to a savings value of $14.72 (19 percent) at the company’s current average hourly labor cost of $46 per hour. The source of the remaining savings of $29.82 (37 percent) is not identified. This 37 percent could be located in reduced design cost or the complete elimination of parts through integration and materials optimization. Since this vehicle cockpit includes the HVAC component, the traditional concept cost level is probably in the range of $800 to 850. A $79 reduction should represent a near 10 percent improvement.

To summarize, the proposed assembly plant design actually represents a mix of advanced use of modules in assembly, traditional outsourcing, and restrictions in paint shop and body shop flexibility. This combination of changes in the traditional plan for a small car assembly plant reduces plant investment to two-thirds to one-fourth of traditional fixed cost by the assembly firm. The plants are certainly advanced in both level-one and level-two-type modularity. All sub assembly and build up lines in general assembly are sourced to the module suppliers. These suppliers are granted full concept control of design, as well as complete warranty liability. The cost reductions for the modules promised by suppliers range from 10 to 20 percent from the traditional concept levels.

The authors of this report estimated potential UAW membership loss based on known manning reductions for these two proposed plants. The estimate is based on a case assumption of the described plan being applied to all small car and truck plants with UAW locals in the United States. UAW job loss would total 23,000. Yet it became clear in this calculation that 13,000 of these job losses arose because of the adoption of contiguous stamping as opposed to the use of large centralized stamping plants. This portion of the total job loss cannot be attributed to modularity. Instead, it merely represents the adoption of traditional lean stamping operations as practiced by the typical Japanese motor-vehicle firm. In fact, a number of the remaining 10,000 job reductions can also be attributed to the use of lean manufacturing practices (for example, reductions in use and number of skilled trades) and not to the use of modules in assembly. Finally, the membership loss of 23,000 is certainly not a net job loss figure for the entire industry. The bulk of the manufacturing jobs once located in assembly plants would certainly be relocated to supplier facilities within 60 minutes distance from the plant.[8]

Current Modular Activity in World Assembly Plants

This section reviews the current state of modular activity in assembly plants worldwide. References for this review are provided at the end of this report. Our information is also derived from telephone interviews of OEM and supplier representatives.[9]

There are (at least) three primary models for the physical integration (i.e., proximity of module supplier location to the vehicle assembly process) of module suppliers. A taxonomy of known vehicle programs that include some use of modules is shown in table 3. It is important to note that not all of these examples are level-two modules and it is likely that many are assembly modules.

Table 3
Modular Activity in World Assembly Plants

Audi	DaimlerChrysler	Fiat	Ford	General Motors
A3 (C) A4 (C) A6 (C)	Concorde (C) Dakota (C) Intrepid (C)	Brava (B) Bravo (B) Lancia Wagon (B) Palio (B)	Amazon (B) Fiesta (B) Ka (B) Mondeo (B) Puma (B) Volvo- Gottenburg (B)	Astra (B) Blue Macaw (B Zafira (B))
MCC	**Mercedes**	**Renault**	**Skoda**	**Volkswagen**
Smart Car (A,B)	A Class (C) M Class (C) V Class (C)	Clio (B,C) Laguna (B,C) Megane (B,C) Scenic (B,C)	Felicia (A) Octavia (A)	Beetle (B) Bora (B) Golf (B) Lupo (B) Passat (B) Truck (Resende) (A)
(A)=Suppliers in plant (B)=Adjacent supplier park (C)=Delivery from satellite facilities				

The physical integration model that includes the least stringent proximity requirement is the satellite facility model. Supplier facilities are located at a distance from the vehicle assembly facility and modules are delivered to the assembly facility under constraints similar to those of ordinary components. The distance these facilities are from the vehicle assembly plant can vary significantly. An example of satellite facility modularity is the cockpit module built by Delphi for DaimlerChrysler's Mercedes M Class SUV in Tuscaloosa, Alabama. Delphi coordinates 46 suppliers and manufactures the cockpit in a facility 10 minutes away from the Mercedes assembly facility. The cockpits are shipped just in time, in sequence, with installation in the vehicle complete within 120 minutes of the electronic order for the cockpit. Conversely, that same Delphi plant delivers similar cockpit modules to the Magna Steyr-Daimler-Puch assembly facility in Graz, Austria, with a six-week broadcast window.

The supplier park model represents a more stringent supplier proximity requirement for module sourcing. In this model, modular suppliers are located adjacent to the assembly facility. Current examples frequently include the suppliers leasing their buildings from the OEM. Ford's assembly facility in Saarlouis, Germany is typical of this modularity paradigm. Saarlouis builds the Focus, Ka, and Fiesta. Twelve suppliers are located in the 50,000-square-meter supplier park adjacent to the facility. Most are housed in one building, which uses a conveyor to carry modules to the assembly line without the use of trucks or forklifts.[10]

Modular assembly facilities in which supplier employees install their own modules into the vehicle represent the most stringent supplier proximity model for modular assembly. In this model, suppliers either own or lease small build-up facilities located adjacent to the assembly plant. The suppliers are assigned a portion of the assembly line, which also may be leased from the OEM, and are responsible for the installation of their respective modules onto the vehicle. An example of this type of facility is Volkswagen's heavy-duty truck facility in Resende, Brazil. At Resende, suppliers assemble trucks from four basic modules: cabin, chassis, engine/transmission, and suspensions/axles/wheels. The suppliers are responsible for quality, inventory control, and wages. Volkswagen maintains a staff to oversee the operations and provides basic necessities such as air conditioning and electricity.[11]

Current North American Activity

Current, modular, vehicle-assembly activity in North America consists solely of satellite facility sourcing. The DaimlerChrysler, Dodge City truck assembly facility in Warren, Michigan uses a chassis line to build up Dodge Dakota chassis in a format similar to that of the Campo Largo, Brazil, facility where Dana Corporation provides the rolling chassis. As mentioned previously, Delphi provides complete cockpits for the Mercedes M Class for the Tuscaloosa, Alabama facility. The M Class also uses a tire/wheel assembly provided by supplier T&WA and a front suspension upper corner module provided by Arvin Industries. BMW's facility in Spartanburg, South Carolina, uses rear axle assembly and fuel systems modules for BMW's Z3. Textron provides cockpit modules for several vehicles, including the Jeep Grand Cherokee, built at North Jefferson Assembly in Detroit, DaimlerChrysler's LH vehicles built in Bramalea, Ontario, and the Chevrolet Malibu, built in Oklahoma City, Oklahoma.

Although modular activity in North America is currently less ambitious than in Europe or South America, emerging plans for several, new, vehicle-assembly plants suggest that modular concepts may be increasingly used in the near future. DaimlerChrysler's new Jeep facility in Toledo, Ohio, for example is scheduled to begin production of the Jeep Cherokee KJ in January 2001 and is expected to make use of several modules.[12]

Current European Activity

Modular assembly techniques are applied more extensively in Europe. Because the European market is dominated by unibody passenger cars, modularity efforts are concentrated on those vehicles. One notable exception is the Magna Steyr-Diamler-Puch assembly facility in Graz, Austria, which assembles Jeep Grand Cherokee and Mercedes M Class sport utility vehicles. This facility uses cockpit modules sourced from North America by Textron and Delphi.

Facilities with supplier parks are increasingly common in Europe and are used by virtually every major vehicle manufacturer in at least some of its facilities. A partial list includes Ford's facilities in Valencia, Spain; Genk, Belgium; and Saarlouis, Germany.[13] All three facilities manufacture a variety of passenger cars and use both supplier parks and modules sourced from distant facilities. Volkswagen also uses both supplier-park and distant-facility sourcing of modules in facilities manufacturing VW's, Seats, and Skodas in Martorell, Spain; Brussels, Belgium; and Wolfsburg, Mosel[14] and Emden in Germany, among others.

General Motors' new Astra platform, built for Opel and Vauxhall in facilities in Bochum and Eisenach in Germany, Antwerp in Belgium, and Ellesmere Port in England, makes extensive use of modules.[15] General Motors has recently begun construction on a replacement for its Russelsheim, Germany, facility. The new facility, scheduled to begin production in 2002, will make extensive use of modularity to produce the Vectra and the Omega off GM's Epsilon platform.[16,17] More than 30 suppliers are expected to be housed in the adjacent supplier park and will build about 60 different modules. Renault has a supplier park at its Flins, France, assembly plant and opened a new supplier park at its Sandouville, France, facility in August 1999.[18] The 31,000-square-meter supplier-park will initially house five suppliers who will lease the buildings they occupy from Renault.

Fiat was perhaps the first company to make extensive use of contemporary modular principles to produce a car. Fiat's Cassino, Italy, plant began building the Tipo from 14 modules in 1984.[19] Currently, Fiat uses modularity at several European facilities, including Melfi, Italy, in addition to maintaining several highly modular facilities in South America.[20]

Europe's most ambitious modular facility is DaimlerChrysler's Smart Microcar assembly plant in Hambach, France. The factory's layout resembles a cross, with the assembly line easily accessible to suppliers dropping off modules near the point on the assembly line where they are added to the vehicle. DaimlerChrysler employees manufacture the Smart car from modules sourced from suppliers housed in an adjacent supplier park. The Smart car was designed for modular construction and features a spaceframe (dubbed the "Tridion") which is visible on the inside and outside of the vehicle and acts as a portion of the exterior. The spaceframe can be purchased in two different colors to complement the car's color scheme and provides for easier addition of modules during the build process. Lackluster sales of the Smart have left the Hambach facility on uncertain footing and its future in question.

Current South American Activity

South America has seen the most highly modular assembly efforts to date. DaimlerChrysler and Volkswagen both have highly modular truck-assembly facilities in Brazil. DaimlerChrysler's Dodge Dakota facility in Campo Largo sources a rolling chassis, complete with suspension, brakes, and fuel-delivery system, from Dana Corporation.[21] Volkswagen's heavy-duty truck facility in Resende is the only modular facility currently in operation using supplier employees on the assembly line.[22] It is noteworthy that these facilities manufacture body-on-frame trucks—perhaps the ideal platform for application of modularity. Body-on-frame construction allows for easier installation of modules to the vehicle and to further reduce complexity, Volkswagen has limited the build options for the Resende-produced vehicles.

Fiat has modular assembly facilities in Bertim, Brazil, and in Cordoba, Argentina. Both plants manufacture the Palio and Siena off Fiat's 178 global small-car platform. Cordoba is the newer of the two plants, having begun production in mid-1998. Fiat only provides the powertrain, electronics, and assembly of vehicles in Cordoba. All modules, stamping, and painting are provided by suppliers—many housed in the adjacent supplier park.[23]

Renault's Ayrton Senna plant in Curitiba, Brazil, began production in December 1998 and was its first assembly plant to include a supplier park. The supplier park houses four suppliers who provide seven modules. The Senna plant currently builds the Scenic and production of the Clio is planned for late 1999. Renault also plans to add an engine plant and gradually increase capacity to 120,000 by 2001.[24,25]

Both Ford and General Motors have South American modular-assembly facilities currently under construction. Ford's Amazon facility, delayed by a dispute over incentives, will be located in Bahia, Brazil, and will produce the Fiesta and B226 small van. Construction began in October 1999 and Ford expects the first vehicles to be produced some time in 2001.[26] General Motors' Blue Macaw facility is under construction in Gravatai, Brazil, and will produce the Corsa. Blue Macaw is expected to start production in mid-2000 and the investment is expected to be approximately $600 million.[27]

A Short Survey of Supplier Modularity

Thus far, we have reviewed a project briefing of a major automaker's plans for new modular assembly plants and also current modular activity in world assembly plants. However, we must also consider input from the module suppliers themselves in order to complete our review of the likely use and impact of modules in vehicle assembly. For this purpose, we completed a short survey of major module suppliers in North America in the early summer of 1999.

A short questionnaire on supplier modularity was developed for this study. The instrument contains six major questions. The supplier respondents were first polled on their company's current and projected sales of modular components. Respondents were then asked to estimate the overall cost savings potential of the switch from traditionally assembled components to the use of modules in assembly. A follow-up question was asked on the sources of specific sources of cost reductions achieved through modularity. An open-ended question was included on needed changes in the manufacturer/supplier relationship in order to facilitate the design of optimized modules. Two additional questions focused on the economic development aspects of modularity in terms of supplier distance from the modular assembly plant and the need for new supplier facility investment. Finally, the sixth question attempted to identify major drivers and barriers to modular sourcing in the eyes of module suppliers.

The sampling frame for the survey was developed through the use of the 1999 *Automotive News* list of the 150 largest North American suppliers. Forty-two potential respondents were selected from this source on the basis of North American automotive sales levels and the nature of major products produced by the companies. Only makers of discrete parts and components, not materials (e.g., paint or glass) were selected for the survey.

It was decided that the most appropriate respondent at each firm would be the vice president or similar manager of engineering. It was thought that these individuals would possess the greatest knowledge of current and future company initiatives in the area of modules. However, about half of the selected companies were OSAT affiliates.[28] In order to boost the likelihood of response in these cases, the questionnaire was mailed to the assigned representative of selected OSAT affiliate firms. Where possible, affiliate representatives who work in engineering or technical R & D were selected. In the case of non-affiliated companies, the name of the executive head of engineering was obtained by telephone. The questionnaires were mailed in the first week of June 1999.

Several methods of follow-up were used. A total of 22 questionnaires were returned, for a final survey response rate of about 52 percent. The responses were then entered into Microsoft Excel and results shown below were calculated.

North American sales for the 22 responding firms totaled $61.8 billion in 1998. Worldwide sales volume for these firms in 1998 was $124.5 billion.

Survey Results

Current and Future Expected Modular Activity

The natural starting point for this survey was to develop an understanding of the current status of level-two (design) modules and the respondents' expectations for future business opportunities. To this end, the respondents were asked to indicate which of a group of key modules they currently provide and which they intend to provide in five years (table 4). Although this list was not intended to be all-inclusive, it did include many of the more complex modules most commonly expected to be viable opportunities in the coming decade. Given the number of respondents, it is apparent that many of the companies will be active in several module sectors. This is an indication that automotive suppliers see the move to modular assembly as an opportunity to increase their product portfolio and value added.

For purposes of analysis, we chose to segregate the respondents into three categories based on the modules they produce. These three categories are: front end/chassis, rolling chassis/engine, and interior. Where applicable, we have highlighted differences in responses between three groups.

Table 4
Current and Future Modular Supply

For the following partial list of automotive modules, please indicate which ones you currently provide, and expect to provide in the next five years. Please consider global operations. *(Note: components listed for each module are not necessarily all inclusive.)*		
Automotive modules	**Currently provide**	**Expect to provide in five years**
Group 1, 14 Respondents		
Front end module (fascia, radiator support, bumper, lighting)	2	4
Rear end module (bumper, fascia, lighting)	0	3
Front corner module (suspension, drive shaft, brakes, steering components)	5	11
Rear corner module (suspension, brakes, drive shaft for trucks and RWD)	5	10
Group 2, 12 Respondents		
Fuel delivery module (fuel tank, pump, filter, lines)	0	5
Engine exterior/intake (gaskets, intake and exhaust manifolds, fuel injectors, spark plugs, spark plug wires, ECM)	2	5
Rolling Chassis (frame, suspension, brakes, tires, fuel tank, fuel pump, fuel lines, brake lines, steering components)	0	6
Group 3, 15 Respondents		
Instrument panel module (instrument cluster, IP, air bags)	6	8
Cockpit module (instrument cluster, IP, air bags, console, pedals)	5	10
Seat module (seat, rails, power mechanism)	4	5
Headliner module (headliner, lighting, storage console, sunroof)	3	4
Door inner module (glass, power controls, trim)	2	8
Complete interior module (instrument panel, seat module, headliner)	0	3
Wiper module (wiper motor, washer fluid pump, wiper arms and blades)	3	3

The interior of the vehicle has received a great deal of focus over the past several years. The consolidation of the interior supplier sectors and the subsequent concentration of sales into a select group of companies have been highly visible characteristics of this sector. Six of the respondents said they currently provide design module instrument panels, while only three said they currently deliver seats. Although there has been a great deal of interest in the interior as a complete module, it appears it still may be several years before such a module is delivered.

Eleven of the 22 respondents said they intend to produce front corner modules within five years, and ten said they would be capable of delivering rear corner modules. One argument for modularity suggests that cost savings may in part come from increased scale economies at the supplier level. Any potential for scale economies may be lost temporarily with 10 or 11 companies competing in the same module sector.

The interior supplier sector may be a better indication of future supplier-industry structure and thus may give insight into the future of the corner module sector. Three companies indicated they intend to provide complete interior modules by 2004. These companies represent what has been referred to as the new tier 0.5 system integrators. Yet, five other companies indicated they expect to provide instrument panels and seven others said they intend to provide the cockpit module. These companies may be more similar to the current tier-one suppliers—offering high value-added engineering and manufacturing of complete component sets or even modules, yet not capable of combining modules or systems into complex modules. Certainly a concern for these tier-one suppliers will be the identity of future customers. It is not clear whether their customers will continue to be the vehicle assemblers, or increasingly will be tier 0.5 suppliers. Some of these latter firms are currently competitors.

An intriguing result is the number of companies that indicate they intend to offer rolling chassis within five years. No less than six companies indicated they expect to be capable of delivering a rolling chassis by 2004. The high profit margins of light trucks, combined with light trucks' increasing share of light vehicle sales, has led many companies to attempt to gain a larger portion of light-truck manufacturing. Currently one company delivers a much publicized and highly visible rolling chassis. However, the rolling chassis currently offered is an assembly module (or level-one module), with much of the original design work being done by the manufacturer. Nonetheless, the rolling chassis currently being delivered is an important step and may be indicative of future programs. Those companies that expect to deliver rolling chassis may represent the move to a tier 0.5 for the corner module group. Much like the interiors sector, it is possible that there will be a "shakeout" and some of those companies that intend to supply rolling chassis will gain tier 0.5 status, while others may trend toward tier one—supplying corner modules to other chassis modules.

The increase in the number of companies that expect to deliver rolling chassis also illustrates the effect of globalization. Although a majority of the companies surveyed were based in North American, they are most certainly global in reach. The rolling chassis will likely not soon see significant application in this market due to structural (i.e., labor) issues within the North American market. However, in an effort to reduce investment costs and meet local content rules in emerging markets, the assemblers may look to partner with these rolling chassis providers in developing markets.

In a further reinforcement of the tier 0.5 supplier concept, some respondents indicated they intend to deliver significant portions of the body (i.e., body chunks), and one respondent indicated they intend to provide a complete vehicle-structure body module within the next five years. Again, a current highly publicized level-one module may give valuable insight. Magna's Steyr-Diamler-Puch assembly facility in Graz, Austria, is an example of a supplier taking assembly responsibility for an entire vehicle. Although Magna did not have control of the design of the vehicles produced, it has positioned itself to take significantly more responsibility for design in the future.

Although no respondents indicated they currently provide fuel-delivery modules, there is expected to be future activity. Five companies said they expect to provide the fuel delivery module in five years. Five companies also expect to provide engine intake/exterior modules in that same timeframe.

The engine presents interesting opportunities and challenges for the implementation of modular sourcing. Over the past decade, much of the design and development of engine accessories has been shifted to suppliers. Yet many of these bolt-on accessories are currently optimized at the component level. The consolidation of these components into some form of a level-two module may be a logical continuation of the current trend. As confirmation of this, it is important to note that when asked to list modules that may not have been included in the list presented, several respondents listed various external engine modules as future business opportunities.

In some instances, the engine itself can be considered a level-two module. This appears especially true for diesel engines, many of which are currently purchased from engine suppliers. This outsourcing of engine technology may be an indication of future manufacturer strategy regarding some new engine technologies. Honda, long considered a leader in the development of low-emission internal-combustion engines has suggested they intend to investigate the idea of selling low-emission engines to other assemblers, and Mitsubishi has certainly attempted to position itself as a leader in direct injection gasoline engines. However, new engine technologies such as direct-injection gasoline engines—or fuel cells—may not be the domain of assemblers. The Ford-ZF joint venture in Batavia, Ohio, is a recent example of a shift in technology (i.e., continuously variable transmissions) leading to willingness to outsource work previously done by a manufacturer.

From the results of table 5, it is apparent that the respondents expect to increase their product line of modules in coming years. Each of the listed modules will see the number of companies that supply those modules to increase in the next five years. However, to illustrate differences it is helpful to investigate participation growth rates (i.e., the number of respondents expecting to build a given module compared with the number currently doing so). To do this, three break points are drawn. They are: new markets—modules that aren't currently provided, but will be in 5 years' time; growth markets—modules that have growth rates of 100 percent or greater in the next 5 years; and mature markets—or modules with 5-year growth rates of less than 100 percent (table 5).

Table 5
Growth Rates for Automotive Module Markets

Participation growth rate (i.e., increase from current to five years from now)	Number of modules	Automotive modules
Increase from 0 (New markets)	4	Rear end, fuel delivery, rolling chassis, complete interior
Increase by 100 percent or more (Growth markets)	6	Front end, front corner, rear corner, engine intake, cockpit, door inner
Increase by less than 100 percent (Mature markets)	4	Instrument panel, seat module, headliner, wiper module

A theme that has developed in this survey is the relative maturity of the interior module supply sector as module suppliers. The breakout in table 5 further suggests that the interior sector is the leader in the automotive industry's move to modularity. Four of the interior modules are classified as mature markets. However other interior modules (cockpit, door inner, and the complete interior) are growth markets. All of the front end/corner chassis modules are growth markets, indicating that there has already been some activity with these modules, but a significant increase in activity is expected in the next five years. Finally, it is noteworthy that rolling chassis and complete interior modules are both classified as new markets, possibly an area of business for the new integrated system (tier 0.5) suppliers. Results shown in table 5 indicate the respondents strongly believe that there is an opportunity to supply more complex integrated modules. Cost estimates for many of the modules currently provided are in the $300 to 500 range. The more complex 0.5-level modules would offer the opportunity for suppliers to triple or even quadruple this level of value added by combining these primary modules into more complex integrated products.

Modular Activity by Vehicle Segment

Modular activity by vehicle segment was also investigated (table 6). Respondents expect that nearly half (45.7 percent) of new compact car programs will employ a significant number of modules by 2004. The forecast for all other segments are in the 30 to 35 percent ranges. Much of the interest in modular assembly has involved small cars. Due to the low profits for these vehicles, assemblers may be more willing to explore new paradigms to lower production costs. Assemblers appear to believe modularity offers the potential for such reductions. Small cars also offer another incentive for increased use of modules. As small car programs become more global in nature, it is possible to use the same footprint—or layout— for plants throughout the world. The modular facility paradigm offers assemblers the opportunity to gain entry into new markets while minimizing their investment burden.

Table 6
Extent of Modularity by Vehicle Segment

For the following vehicle segments, please estimate the percentage of new vehicle programs that will employ a significant number of modules by 2004.	
Vehicle segment	**Percent of new programs using level-two modular assembly by 2004**
	Overall Average n=16
Compact car	45.7%
Mid size car	35.3
Large/luxury	30.0
Minivan	34.7
Compact pickup	34.3
Full size pickup	31.3
Compact SUV	35.0
Full size/luxury SUV	29.7

The rolling chassis is most applicable to the body-on-frame format of pickup trucks and some sport utility vehicles. Yet this segment presents severe barriers for the implementation of true level-two modularity. The vast majority of full-size pickups and truck-based sport utility vehicles are for the North American market. Therefore, any switch to a tier-0.5-supplied rolling chassis for full-size pickups and truck-based sport utility vehicles would require major dislocation of labor. Concomitantly there is little pressure for "greenfield sites" in emerging markets for these vehicles.

Because of the global acceptance of compact pickup trucks, there does appear to be an opportunity for assemblers to implement modularity. Yet the North American infrastructure again presents a significant hurdle. It is possible that future compact pickup truck programs will use level-one rolling chassis that can easily be adapted to emerging market paradigms or the current North American style. Or conversely it is possible that future compact pickup-truck programs may rely heavily on level-two modules—even rolling chassis—with supplier investment in emerging markets, and the use of manufacturer-employed build-up lines to meet the current North American assembly paradigm.

The luxury-car segment also presents some interesting challenges for modularity. With higher profit margins, the luxury segment is under less cost pressure to reduce costs. Yet luxury car assemblers face the challenge of a continually fragmenting market. One respondent commented that the use of modules might allow assemblers to offer a greater number of features while using less assembly-line space.

General Motors is in the initial stages of building a facility for its global rear-wheel-drive luxury car known internally as the Sigma platform. This program includes a new facility located near Lansing, Michigan. To what extent modularity will be used is still unclear. However, it has been widely reported that some elements of the company's highly publicized (and much delayed) Yellowstone project will be incorporated into the Sigma project. A critical advantage for the implementation of modules in the Sigma program is that it involves a new product and a new plant so it will not be tied to previous labor contracts.

Effect on Cost

The supplier respondents were asked to estimate the percent savings associated with the implementation of modular assembly. This comparison was further described as the "percentage savings based on the switch from the current component assembly paradigm to a supplier designed module." Respondents were also instructed to "use the module that you are most familiar with for your estimate." Finally, respondents were asked to describe the module used in their estimate. Therefore, results for this question can be broken out by module group, based on the module for which respondents have provided their cost savings estimates. As shown table 7, the three categories used to group the responses for this question are the same as those used thus far: group 1, front end/chassis; group 2, engine exterior/rolling chassis; and group 3, interior.

Seventeen respondents answered the percent savings question. The mean percent savings are about 15 percent. Fifteen of the seventeen respondents described the module on which they based their estimate of percent savings. The mean percent savings for seven respondents in group 1, or the front-end/chassis module suppliers, is 13 percent. The mean percent savings for seven respondents in group 2, or the interior module suppliers, is 18 percent. The only respondent for group 2 reported an expected savings of 15 percent. Almost all of these respondents commented on the difficulty of making a savings estimate. A variety of reasons were listed for this difficulty. In particular, the suppliers noted that since it was difficult for them or their customers (the “OEMs”) to know what the vehicle firm’s current costs are, it was almost impossible to confidently estimate the true cost savings associated with supplier modules.

The difference in savings percentages between group 1 respondents and group 3 respondents appears to be significant. A follow-up question on the sources or elements of the cost reductions sheds some light on the difference between the two groups. As shown in table 8, respondents were asked to distribute the source of their overall percent savings response across eight elements of cost savings. Fifteen respondents also answered this question for specific modules. Overall, almost 34 percent of the expected cost savings from the use of modules are attributed to potential improvements in assembly wages or productivity. However, group 1 respondents attribute 45 percent of their expected savings to reductions in labor cost. At the same time, interior module, or group 3, suppliers expect only 16.1 percent of their savings to arise from labor cost reductions.

The overall sample expects about 25 percent of cost savings to be derived from improvements in engineering hours, reduced capital expenditures, or design for manufacturing. Almost 18 percent of total percent savings for group 1 module suppliers are expected from these elements. In contrast, group 3 module suppliers expect over 29 percent of the savings in their modules for these reasons. Finally, the overall sample attributes just over 16 percent of expected cost savings to reduced material costs. However, group 1 module suppliers only assign 7.4 percent of their savings to this return, while group 3, or interior suppliers, expect 22 percent of their offered savings is linked to reductions in material costs.

Table 7
Percent Savings from Modular Assembly

Please estimate the percent savings associated with the implementation of modular assembly (i.e., the percentage savings based on the switch from the current component assembly paradigm to a supplier design optimized module). Please use the module that you are most familiar with for your estimate.			
Estimated cost reduction	**Group**		
(Average for all modules) n=17	**1 n=7**	**2 n=1**	**3 n=7**
14.9 %	12.9%	15.0%*	18.0%
Group 1= front/rear/corner, group 2 = engine exterior/rolling chassis, group 3 = interior			

*****Only one response from Group 2 was received.

Table 8
Sources of Modular Savings

With regard to the activities listed below, please indicate where the savings estimated in the previous question will be derived. ***(Note, please estimate the total savings due to design module optimization. Be sure that your estimate adds up to 100 percent.)***			
Elements of cost reduction	**Percent reduction**	**Group**	
	Average n=15	**1 n=5**	**3 n=6**
Assembly labor wages	21.2%	29.0 %	10.3 %
Assembly labor productivity	12.5	16.0	5.8
Reduction of engineering hours	5.2	1.4	4.4
Reduction of capital expenditures	7.7	8.0	8.3
Design for manufacturing and assembly	11.6	8.4	15.4
Material cost savings	16.4	7.4	22.3
Reduced testing and prototyping costs	4.6	1.4	7.8
Component commonization	7.1	5.4	10.0
Group 1= front/rear/corner, group 2 = engine exterior/rolling chassis, group 3 = interior			

A major finding of this modest survey is the difference in cost savings by type of modules supplier. Group 1 module suppliers expect their largest source of savings in the form of reductions of several types of labor cost (45 percent). These same suppliers, on the other hand, expect only 7 percent of their savings to arise from reductions in material use. Group 3 module suppliers expect only 16 percent of their projected savings to arise from lower labor costs. However, they expect over 22 percent of savings from reduced material costs alone, and an additional 29 percent from reduced engineering and investment costs.

The reasons for the differences in the sources of the cost reductions between the two types of module suppliers are based in history. Group 3 suppliers produce interior modules such as seats and instrument panels (IPs). Domestic vehicle manufacturers first outsourced seats in 1986. Almost all the cushion rooms at “Big Three” assembly plants have now been replaced by “sourced seats” produced at lower-wage, independent, interior-supplier plants that use the spray-foam seating technology. IPs have been increasingly produced at independent suppliers such as Magna, Lear, or JCI, as well. Therefore, gains from lower-cost labor in interior-systems sourcing have already been realized for years in the North American auto industry. Therefore, additional gains to increased modularity in the supply of interior components would primarily result from increased integration in design and the rationalization of fixed cost. In other words, interior module suppliers are projecting pure gains in efficiency from Level-2 modularity—systems rationalization. These cost improvements are estimated at 18 percent.

Chassis and front-end module suppliers, on the other hand, are projecting savings based primarily on the assumption of new business. Corner modules are still produced, for the most part, inside of traditional vehicle assembly plants. A possible first step to moving this work outside to independent suppliers is level-one modularity. The short-run return to such outsourcing is reduction in labor costs. Returns to increased design efficiency may come later in time, as was apparently the case for interior modules. This implies two stages to the modularization of sections of the motor vehicle. The first stage is both motivated and characterized by level-one modular assembly—the replacement of high internal-labor assembly cost with supplier assembly at lower wages and hopefully higher productivity. A second, later stage brings additional returns in the form of integration and more efficient design engineering. Whether the second stage occurs may depend on the degree of concept freedom granted to suppliers or the cross–system limitations inherent in the module in question. Total potential gains to the two types of modularity can be enormous. If the first stage brings a 13 percent rate of savings, as the seven group 1 suppliers tells us in our survey, the second stage may be to increase savings by an additional 18 percent as promised by group 3, interior module suppliers.

What is implied by a 15 percent savings due to the use of modules? Clearly the portion of savings generated by lower assembly wages, higher assembly productivity, and better design for manufacturing and assembly will occur in the overall category of assembly cost. At least a portion of the cost element of reduced capital expenditures also refers to savings in assembly-plant investment. Since it is generally agreed by many analysts that about 20 percent of vehicle cost is located in assembly-plant operations and the production of major stampings, the combined source percentage of 53 percent for the factors listed above can be applied to this assembly cost share. In other words, 53 percent of the 15 percent overall savings percentage should be located in assembly cost. The other 47 percent of the 14.9 percent savings would be located in the 80 percent of vehicle manufacturing and engineering costs incurred outside of assembly.

The Proximity of Module Suppliers

The use of modules will require the transfer of thousands of jobs previously located in assembly plants to supplier module assembly plants. Therefore, the approximate distance of these supplier plants from their assembly customer plants is an important question in economic development at the local and state level. New modular plants are being proposed by several automakers who are asking for substantial public subsidies and tax benefits. A critical factor in the public valuation of such subsidies is the total number of direct jobs created or preserved in a given region.

Our survey asked respondents to estimate required maximum delivery time for modular programs that necessitate proximity to an assembly facility. Eighteen respondents answered this question. Results are shown in table 9. The mean response for required delivery time is 78.8 minutes. We did not ask respondents to estimate delivery time for any specific module. However, current suppliers of group 1 modules (12 cases) reported a mean delivery time of 78 minutes; group 2 suppliers (8 cases) reported a mean of 91 minutes; and group 3 respondents (14 cases) a mean delivery time of 62 minutes. Respondents to this question stated that delivery time would vary by the type of module. Interior components, which typically vary by color and trim style, would require the “shortest window.” Chassis assemblies such as corner modules would receive a longer window, and powertrain or fuel-system components could be located at the furthest distance from the assembly plant.

Table 9
Proximity of Modular Assembly Plants

For modular programs that require proximity to an assembly facility, how close will suppliers be required to locate? Please give your answer in maximum delivery time (minutes).			
Maximum delivery time	**Group**		
Overall Average n=18	1 n=12	2 n=8	3 n=14
78.8 Minutes	77.9 Min.	90.6 Min.	61.5 Min.
group 1= front/rear/corner, group 2 = engine exterior/rolling chassis, group 3 = interior			

Results for this question are encouraging for economic development at the state level. All module-supplier assembly should occur within the confines of most automotive states except for one or two borderline module-assembly facilities. On the other hand, a 79-minute window for delivery time could allow a number of modules suppliers to locate production outside of the typical automotive county. However, this is less likely if a more restrictive definition of "broadcast time" is used in place of simple delivery requirements. Broadcast time refers to the actual amount of warning a supplier would receive for a change in module orders. A 79-minute broadcast time limit would require, it is thought, suppliers to locate closer to assembly customers than a similar delivery period.

New Investment in Supplier Facilities

The supplier respondents were asked if the implementation of modular assembly would require them to invest in new facilities. All 22 respondents answered this question. Only one respondent replied in the negative. This question, however, elicited considerable open-ended comment from the respondents. Eight respondents discussed the necessity of building new assembly and scheduling facilities close to their assembly customers. Four respondents stated that the new testing-and-validation and research-and-development facilities would have to be built by modular suppliers. Two respondents said both types of facilities, assembly and research and development, were likely to be major investments. All of the respondents indicated considerable new investment and its associated risk are certainties associated with the expanded use of modular assembly.

Success Factors for Change

The respondents were asked to describe what changes are necessary in current manufacturer/supplier relationship to facilitate level-two modularity. The two foremost issues highlighted in their responses were earlier supplier involvement and a willingness of the assemblers to '"let go" of design, engineering, and management. Several respondents indicated that if modularity is to be successful, the assemblers will need to allow the suppliers to gain earlier entry to new car programs while the vehicles are still early in the developmental stage. It is interesting to note that several respondents also noted that the assemblers need to truly commit to the idea of modularity.

As described previously, a benefit of level-two system modularity is purportedly to increase efficiency in component and vehicle-design engineering. Several assemblers have indicated a desire to shift vehicle (i.e., module) design and engineering to their suppliers, thus reducing the amount of fixed assets for the manufacturer. To achieve the hoped-for reductions, it will be necessary for the suppliers to take greater or complete control of the modular design, engineering, and even sourcing of lower-tier parts and components. The continued use of shadow or "ghost" engineering by assemblers would greatly limit the potential gains of modularity.

The respondents were asked what they perceive as the drivers for the implementation of modular assembly from the point of view of the assemblers. Among the 16 factors listed, five stood out as most important (table 10). As a group, respondents indicate that assembly labor wages and productivity are critical drivers for the assemblers in the desire to move to modular assembly. Yet similar to the earlier question regarding cost-savings estimates, there is one area where the groups differ significantly. The chassis suppliers see assembly wages and productivity as much more critical than do the interior suppliers. However, the interior suppliers see materials-cost savings and reduction-of-engineering cost as more important to the manufacturers than do the chassis suppliers.

Table 10

Drivers of and Barriers to Modularity

In your opinion, what are the drivers and barriers for implementation of modular assembly *from the point of view of the vehicle assemblers*? Please rate the following factors for implementation, where 1 = not important, 3= somewhat important and 5 = critically important.				
Factors for implementation	**Mean rating**	**Group**		
	Overall n=22	1 n=14	2 n=12	3 n=15
Assembly labor wages	3.7	***4.2***	***4.1***	***3.2***
Assembly labor productivity	3.6	***3.9***	***4.0***	***3.2***
Faster delivery of ordered cars to the customer	3.6	3.8	3.8	3.7
Improvement of quality	3.5	3.7	3.7	3.5
Reduction of capital expenditures	3.4	3.9	3.6	3.2
Transfer of warranty cost to suppliers	2.9	3.3	3.1	2.9
Technology innovation	2.9	2.6	2.8	3.2
Platform reduction	2.8	3.4	2.6	3.2
Material cost savings	2.8	***2.4***	***3.1***	***3.3***
Reduction of engineering cost	2.7	***2.3***	***2.3***	***3.2***
Faster vehicle design and development	2.7	2.8	3.0	2.9
Reduced testing and prototyping costs	2.5	2.4	2.4	2.8
Design for manufacturing	2.0	1.6	1.8	2.8
Design for assembly	1.9	1.2	2.0	2.5
Component commonization	1.6	2.0	1.3	2.0
Product flexibility	1.3	0.8	0.7	1.4
group 1= front/rear/corner, group 2 = engine exterior/rolling chassis, group 3 = interior				

The automotive industry is under increasing pressure to reduce time from order to delivery. As assemblers and retailers experiment with online selling, benchmarks set in other industries are leading assemblers to grapple with an archaic vehicle-ordering-and-delivery system. Currently the industry standard is several weeks. Assemblers hope to reduce that to several days. Respondents view this desire to reduce time to market as an important driver for modularity.

As assembler's look to new (emerging) markets, modularity offers them the opportunity to shift much of the investment risk to their suppliers. With new modular assembly plants costing as little as a quarter of a traditional facility, the assembler is far less exposed, but conversely, the suppliers are more heavily invested, and therefore more vulnerable to the turbulent swings so common in emerging markets.

Conclusions

A major finding of our survey of major component suppliers is the pattern of future growth in module products. Suppliers are currently providing a number of level-two modules. These products are concentrated in the interior sector (seat, cockpit, and instrument panel), and front and rear corner modules. However, the corner-module market will be subjected to increasing competition. Eleven of the twenty-two respondents said they intend to produce front corner modules within five years, and ten suppliers said they expect to deliver rear corner modules in that same time frame. Additionally, six companies expect to be capable of delivering a rolling chassis by 2004. Such intense competition may produce difficulties. One argument for modularity suggests that cost savings may in part come from increased scale economies at the supplier level. Any potential for scale economies may be lost temporarily with ten or eleven companies competing in the same module sector.

Survey respondents expect that nearly half (45.7 percent) of new compact car programs will employ a significant number of modules by 2004. The forecast for all other segments are in the 35t-o-30-percent ranges. Much of the interest in modular assembly has revolved around small cars. Due to the lack of profitability of these vehicles, assemblers may be more willing to explore new paradigms to lower production costs. Assemblers appear to believe modularity offers the potential for such reductions. Small cars also offer another incentive for increased use of modules. As small car programs become more global in nature, it is possible to use the same footprint—or layout—for plants throughout the world. In fact, about 70 percent of the vehicles assembled worldwide with the use of major modules today are compact or subcompact car models. The modular facility paradigm offers assemblers the opportunity to gain entry into new markets while minimizing their investment burden.

This study reviewed a major automaker's plan for the extensive use of supplier designed modules in the assembly of small cars. That company reported cost savings through the use of modules that ranged from 10 to 20 percent of the cost of traditional-sourced components. This firm expected a 10-percent reduction, at least, in the overall cost of the vehicle gained through the use of modular assembly. This company also expects its typical dollar investment in small car assembly and stamping to fall by 75 to 80 percent.

The use of design modules may have significant implications for the restructuring of the North American automotive industry. The industry will see the creation of new super-system suppliers who combine separate systems into modules. These suppliers have been recently tagged as *0.5* suppliers to separate them from the old definition of first-tier systems suppliers (*1.0* suppliers). A 0.5, integrated system supplier might offer to produce the entire interior of the vehicle including the cockpit with HVAC. This product would also include seats, the instrument panel, driver controls, interior trim and the entertainment system. The total price could exceed $1,500 per vehicle. Typically, large component products rarely exceed $400 in price today, but super-system modules could average $800 to $1,500 per unit in revenue. The overall profitability of such a product, of course, depends not only on the margins obtained, but also on the needed investment to develop or acquire the capacity to produce such large components. Effective partnering with lower-tier suppliers may be just as key in this process as the efficient acquisition of new capacity.

Our survey results of suppliers included responses to a question on the savings percentage that can be attributed to the use of supplier-designed modules in place of traditional components in assembly. Overall, the supplier respondents reported average savings of 15 percent. The suppliers expect 34 percent of the savings from the use of modules to be lower labor wages and higher labor productivity in supplier modules assembly plants. An additional 25 percent of the savings are attributed to improvements in engineering efficiency, reduced capital expenditures, and better design for assembly. Finally, 16 percent of the savings connected to the use of supplier modules are attached to reductions in materials cost.

Significant differences in expected cost savings were present for two major types of suppliers. Interior-module suppliers reported expected savings of 18 percent, while chassis module suppliers promised a smaller savings reduction of about 13 percent. Further, the bulk of savings promised by chassis-module suppliers are in the form of reduced labor costs, while the interior suppliers source most of their savings to reductions in material costs and engineering effort.

Our survey asked respondents to estimate required maximum delivery time for modular programs that necessitate proximity to an assembly facility. The mean response for required delivery time is 79 minutes. Results for this question are encouraging for economic development at the state level. All modular assembly, then, should occur within the confines of a given automotive state except for one or two borderline assembly facilities. On the other hand, a 79-minute window for delivery time could allow a number of module suppliers to locate production outside of the typical automotive county. However, this is less likely if a more restrictive definition of “broadcast time” is used in place of simple delivery requirements.

The supplier respondents were asked if the implementation of modular assembly would require them to invest in new facilities. Only one respondent replied in the negative. This question, however, elicited considerable open-ended commentary from the respondents. Many respondents discussed the need for new assembly-and-scheduling facilities close to their assembly customers. Other respondents stated that some combination of new testing-and-validation and research-and-development facilities would have to be constructed by modular suppliers. Finally, some respondents said that both types of facilities, assembly and research and development, were likely to be major investments.

Our survey respondents were also asked what they perceive as the drivers for the implementation of modular assembly from the point of view of the assemblers. Among the 16 factors listed, five stood out in importance. As a group, respondents indicate that assembly labor wages and productivity are critical drivers for the assemblers in the desire to move to modular assembly. However, the chassis suppliers see assembly wages and productivity as much more critical than do the interior suppliers. Conversely, the interior suppliers see material-cost savings and reduction of engineering cost as more important to the manufacturers than do the chassis suppliers.

Finally, our respondents were asked to describe what changes in current manufacturer/supplier relationships are necessary to facilitate level-two modularity. The two foremost issues highlighted in their responses were earlier supplier involvement and a willingness of the assemblers to '"let go" of design, engineering, and management. It is interesting to note that several respondents also noted that the assemblers must "truly commit to the idea of modularity." In fact, there is yet no developed industry consensus on the potential of automotive modularity. Groups as diverse as union leadership, assembly plant managers, vehicle engineers, and not a few automotive consultants remain very skeptical of the daunting prospect of automotive modules. Other meaningful changes, of course, have met such resistance before in the auto industry's history.

Endnotes

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