Project Report to International Motor Vehicle Program (IMVP), M.I.T.

**Modularization and Outsourcing: Implications for the Future of Automotive Assembly
"Management of the Extended Enterprise" Research Team**

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This report opens with the overview summary of the project -- the rationale, research questions, and research design - that we have been sending IMVP sponsors to win their participation. It then relates our research activities to date, and closes with a list of the next steps we anticipate.

Overview

Twice in this century, automotive assembly has been the setting for dramatic innovations in production organization that have transformed the basis of competition in the auto industry. Henry Ford's mass production and Taiichi Ohno's lean production are both systems of interrelated practices held together by a core "logic" - powerful ideas shaping how we think about "making things". As we approach the second century of the car, there are important debates about whether, once again, auto manufacturing will strike off in a new direction -- commonly described as "modular assembly." Our IMVP research team aims to contribute to this debate through the research project described below.

Deverticalization through the outsourcing of production from the large automakers to their suppliers has been a dominant trend during the 1990s, including the transfer of component design responsibility as well as manufacturing. A related trend is the effort to develop more modular designs, i.e. self-contained functional units with standardized interfaces that can serve as building blocks for a variety of different products. These trends have been visible in other industries for some time, but they are relatively recent in the auto industry; as a result, the implications are still not clear. In industries such as consumer electronics and personal computers, the ultimate consequence of extensive outsourcing is often that the final customer, i.e. the Original Equipment Manufacturer (OEM), manufactures very little in-house. When extensive outsourcing is combined with more modular designs, the outcome can be a dramatic reshaping of the value chain. We want to investigate the extent of these trends in the auto industry and evaluate the implications for the role of automotive assembly and the structure of the entire industry, by doing case studies of specific modules.[2]

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[1] The above listed individuals are the researchers who have received IMVP funds directly. Also involved in the research are the following: Prof. Taka Fujimoto (Tokyo University); Prof. Kentaro Nobeoka (Kobe University); Prof. Fiona Murray (Said Business School, University of Oxford); and Prof. Koichi Shimokawa (Hosei University). The primary Ph.D. student on this project to date is Max Warburton, although Sebastian Fixson at MIT may become involved as well.

[2] We will also study these issues during the third round of the International Assembly Plant Study, planned for 1999. In Round 3, we will once again tap the international sample of 70+ plants that participated in previous

One important motivation for doing the case studies is the great ambiguity and confusion in how these terms are used. It is generally assumed that modularization and outsourcing go together -- that when designs become more modular, they are also more likely to be outsourced. We question this assumption and will examine all possible interactions of these trends. Outsourcing may continue to occur primarily for small subassemblies, while modular designs might be kept in-house. We also take no position on whether or not modularization and outsourcing are good or bad developments or whether they represent the future of the industry. Our goal is to provide greater clarity about the meaning and extensiveness of current trends towards modularization and outsourcing; to describe which approaches to modularization and outsourcing are most common across the industry; and to generate insights about the implications of these trends for the future.

Three Scenarios

We offer three scenarios that capture a range of possible outcomes with respect to modularization and outsourcing. **Scenario #1** is familiar from the computer industry:

1. Modularization of designs, with components that adhere to internationally-accepted technical standards and a common interface that allows easy mixing and matching of elements, combined with:

2. Outsourcing of modules from the OEM to stand-alone, specialized suppliers who have major responsibility for module design, for meeting OEM cost/quality/delivery requirements, and for coordinating the efforts of their upstream suppliers. This combination potentially leading to:

3. Commoditization as an ever-present threat for these suppliers, given relatively low barriers of entry into module manufacturing, and the potential for economies of scale from standardized designs, and:

4. Globalization of production capacity in search of the best combination of low factor costs, proximity to OEMs, and a strategy of "build where you sell" to reduce time between order placement and fulfillment. The logical outcome of all of the above being:

5. Contract assembly -- easy-to-assemble modular designs, OEM outsourcing of all non-core capabilities, commodity competition that reduces margins, and the risk of building independent assembly capacity, given volatile markets.

Scenario #2 is based on strong counter-arguments against the first scenario being likely to take hold in the automotive industry, including the following:

1. Automakers won't want to move to modular designs that homogenize the distinctive "look and feel" of their vehicles. Standardized components, whether simple or complex, increase the risk of "look-alike" vehicles and decrease opportunities for product differentiation based on styling, driveability, level of functionality, and optional equipment.

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rounds of this research (in 1989 and 1994) to gather longitudinal data on key variables and to explore new issues, including the prevalence of outsourcing and the use of modules.

2. Automakers won't be able to move to modular designs that are standard across the industry because such modules can't meet technical parameters of the overall product. Size/weight/functionality requirements vary widely across different models and product segments, limiting the potential utilization of any one module (and hence the opportunity for scale economies). In addition, many automotive subassemblies include a complex mix of technologies that can be difficult to integrate without compromising some dimension of performance.

3. Modules for key subsystems would be too critical to automaker "core capabilities" to be outsourced to suppliers. Maintaining the integrity of product designs is a critical responsibility of the OEM with a product as complex and subject to regulation as the automobile. With a heavy outsourcing of modules, suppliers would, of necessity, be taking on more of that responsibility yet without the overview to guarantee design integrity. Furthermore, very few suppliers possess the engineering and manufacturing capabilities to execute a complex module effectively. Even if appropriate suppliers could be found, OEMs would risk the loss of important expertise by relinquishing module design and manufacturing to them.

4. Outsourcing of modules potentially shifts process know-how and associated product knowledge to competitors, via shared suppliers, as well as shifting power to suppliers who control key modules. OEMs will want to forestall a move to industry-standard modules to protect proprietary process and product knowledge and to maintain dominance in their relationship with suppliers.

Scenario #3 is a hybrid of the first two scenarios -- which stake out the extremes of the debate -- and is representative of alternatives in the middle of the spectrum:

Modular design for some subsystems	--->	But not others where costs outweigh benefits
Modules that are automaker-specific	--->	With OEMs avoiding/blocking industry in their design and functionality technical standards and common interfaces
Only some modules outsourced	--->	Critical modules produced by OEM, much to suppliers outsourcing of non-modular components

Research Questions

This range of scenarios demonstrates, more than anything, the huge number of unanswered questions about modularization and outsourcing and their joint implications for automotive assembly. We will focus on four critical questions as we begin our case studies, each of which we will explore from the perspective of both the OEM and their suppliers (both first-tier and second-

tier):

     1. What are the costs and benefits of modularization and outsourcing (separately and combined) for OEMs and suppliers? How often do modularization and outsourcing occur together?

     2. What are the implications of modularization and outsourcing for product design, manufacturing, and distribution at OEMs and suppliers? What are the consequences for organizational structure, work organization, and labor relations? What engineering, production, organizational, and human resource capabilities are needed?

     3. What criteria should be used in order to decide whether or not to undertake modularization and/or outsourcing for a given subsystem or set of components? If decided affirmatively, how should the modularization/outsourcing be managed?

     4. How do moves towards modular designs and outsourcing affect the globalization strategies and supply chain design choices of firms, and the competitive dynamics of the industry? How do past capabilities (and existing supply chain design) of firms affect these strategies and design choices?

Modules for Case Studies
     Our initial case studies will focus on two major subassemblies that can potentially be designed and produced as stand-alone modules: 1) instrument panels; and 2) door structures and inners/"plugs". There is great variation in the extent to which these subassemblies are subject to modularization and outsourcing. Instrument panels (IP) are increasingly being designed in a modular format and built up at suppliers rather than by the assembly plant. Door structures are outsourced by some automakers, but are most commonly still built-up in-house by welding together stamped pieces. Door inners are composed of pieces from many different subsystems (locking, windows, side mirrors, audio, air bags), most of which involve both mechanical and electronic elements. They also form part of the interior trim of the vehicle, and as such must be color-coordinated with the rest of the interior and exterior trim. Many subassemblies that go into a door inner are outsourced, and modular designs for certain of these are becoming more common.

     While pursuing a modular design is appealing, many potential design constraints can limit the extent of modularization. Consider, for example, the idea of having a fully integrated door "plug" containing all the subassemblies described above, customized appropriately, for snap-in insertion into the vehicle during final assembly. Currently the focus of intense study by many automakers and suppliers, the challenges associated with a full door "plug" are manifold. The module supplier must have proficiency with many different materials (metal, plastics, glass) and with the electronics associated with all the door's functionality. Producing the module requires expertise in many different manufacturing processes, from stamping and clinching to welding to painting to complex assembly. Insuring the integrity of the vehicle with respect to door fits and color match is extremely difficult when the full door is produced by the supplier -- or, more likely, when a first-tier supplier functions as "system integrator" for the door plug by coordinating the activities of many second- and third-tier suppliers. In contrast, making instrument panels into a single module is much

simpler because for the most part, just one material (molded plastic) and one subsystem (electrical) is involved. Of these two complex subassemblies, instrument panels are much further along the path to modularization than door structures and inners/"plugs".

Research Activities To Date

We have visited mostly OEMs to date, in the U.S., Europe, and Japan, although we are beginning the supplier interviews. In many cases, an initial visit was necessary to arrange access details, with subsequent visits focused on interviews. These visits often include plant tours, where appropriate.

We have made the most progress at the following OEMs: Ford and Chrysler in the U.S.; Renault, Fiat, and Ford in Europe; Toyota, Honda, Mazda, Mitsubishi, and Fuji Heavy Industries in Japan. In addition, we have initiated contacts with GM in the U.S.; Mercedes-Benz and Volvo in Europe; and Nissan, Suzuki, and Daihatsu in Japan. Among the suppliers whom we have met (or scheduled meetings with)are Delphi, Visteon, United Technologies/Lear, Sommer Allibert, Brose, Meritor, Textron, Marinetti Marelli, Lames, Kuester, Laurecia, and Valeo.

We are already finding substantial variation in OEM strategies for modularization, in decisions about module boundaries, in whether modularization extends into design, and in the degree to which modularization and outsourcing are always coupled. Modularization appears to be most advanced in Europe at present. One European OEM began approaching certain subassemblies as modules in the 1980s, primarily driven by concerns about ergonomics. Their experience with giving modules to suppliers to build has been mixed, but they are actively exploring the possibility of encouraging a group or "coalition" of suppliers to take responsibility for a module on new models. At another OEM, the interest in modules is more recent and is driven primarily by an increase in outsourcing. We learned about one current development project in which 10 modules have been identified and are currently under joint development with first-tier suppliers; interviews with managers at both the OEM and suppliers gave us a good sense of what issues are arising to date. At a third European OEM, we are exploring the simultaneous implementation of modularization with supplier parks at new or retrofitted assembly plants, where the proximity of suppliers facilitates the sequenced delivery and minimizes the logistics cost typically associated with modularization.

In the U.S., interest in modularization is also strong at the OEMs but proponents often encounter internal skepticism about the cost advantages and reluctance to move towards thinking about product design in modular terms (and/or reluctance to rely fully on suppliers to provide a modular design). We have found different opinions at different companies about which modules make most sense from a cost point of view, but general agreement that the real potential for savings come more from design integration than from labor cost reductions. One OEM has developed an extensive organizational infrastructure in support of modularization, having defined a core set of key modules and then creating a task force for each module that includes a product engineering representative. Use of these modules in product design has been largely presented as an option available to platform teams rather than something that is central to product strategy, and as a result, movement towards incorporating modules has been slow. However, there are some strong initiatives

(and active debates) related to modules in one current development project, and we will try to explore this project in detail. At another OEM, we've primarily focused on the manufacturing side to date, visiting instrument panel and door lines at an assembly plant for detailed discussions about design integration, parts count, materials usage, and supplier relations. We expect to meet with product design and engineering representatives at this company during the summer.

Of the three main regional groups, Japanese OEMs appear to be the most cautious about modularization. Doors have been a separate subassembly in the assembly plant for a long time, but instrument panels were typically not organized in this way in the past. Now most companies are enlarging the scope of in-house subassembly for instrument panels, with designs becoming more modular. The OEMs identify the primary advantages to modular design as gains in ergonomics, production leveling, and quality (from the ability to test modules fully before they are installed). They are not (with one exception) currently inclined to outsource modular design. Consistent with what we heard in Europe and the U.S., they emphasized the value of parts integration during design. However, these potential advantages (which include weight reduction, a simpler assembly process, quality improvement, and ease of recycling) are seen primarily for the instrument panel and not (yet?) for doors.

Given this strategic variation, our decision to look broadly at the impact of modularization across the functional areas of the OEM has already proven valuable. Understanding the perspective of OEM product designers and engineers towards modularization will be particularly important, for the path of choosing to do modular designs but to keep the design activity in-house often encounters the skepticism of this group. Outsourcing of a module then becomes as much as a way to force a new design perspective as it is a way to cut costs. Purchasing is clearly concerned about the challenges of achieving cost reductions while avoiding too much dependence on module suppliers, but must first face the reality that supplier capabilities are not always adequate to accommodate the new responsibilities thrust upon them by the OEMs. Manufacturing sees opportunities to save on space and overhead costs, redesign process flow, improve ergonomics, and handle product variety more easily, but often faces the dilemma that the best boundary of a module from a design perspective may be very different from the preferred boundary for producing that module. After-market sales and warranty issues pull in yet another direction, since the very advantages of large integrated modules in terms of design or production may make them hugely expensive to repair or replace.

Furthermore, the interviews we have done with suppliers so far reveal how valuable it will be to compare their perspective with that of the OEM. Modularization is often cited as a primary motivation for the wave of supplier mergers and acquisitions, in order to build sufficient capabilities to take on full responsibility for module design and production. It is clear that the capital market is willing to support this consolidation in the supply chain based on assessment of the potential benefits available to "super-suppliers" that can land high-volume contracts for their modules. These suppliers (and several that are smaller) are busily touting their capabilities to the OEMs, in hopes of gaining contracts for modules that will carry higher margins than the component-based work they have traditionally done. Meanwhile, they are rushing to build up those capabilities, since a barrier to

modularization so far has been skepticism about whether suppliers are ready to fulfill the role envisioned for them in a modular world. Where arrangements to outsource modules are established, suppliers and OEMs typically engage in heated negotiation about the new division of responsibilities this will entail. Who will choose second tier suppliers is one such issue, with some OEMs insisting on control in order to maintain a basic understanding of the underlying cost structure and others preferring to turn over this task to the first tier. For all the potentially thorny issues that emerge during these discussions with the OEMs, on the whole we are finding a lot of excitement among suppliers about the opportunities that modularization offers them.

One powerful idea sustaining the interest in modularization even where it faces skepticism in operational terms is the goal of moving assets off the books of the OEMs to suppliers, in order to reduce their massive size and increase their speed in responding to market opportunities and volatility. This sharing of investment risk and development responsibility also satisfies the urge to focus on core capabilities (e.g advanced technology development, preserving and enhancing the distinctive "look and feel" of vehicles, developing the brand) while simultaneously developing focused capabilities in the supply chain. It may be this idea, more than anything, that is used to move modularization forward as the debates about its cost-effectiveness and its impact on design continue. However, there are still many unanswered questions about the capital investment implications of modularization, in particular the fact that suppliers typically must pay more for their capital than the OEMs. Those higher capital costs may simply be returned to OEMs in the form of higher prices for the modules they buy. Max Warburton is exploring the possibility of doing his Ph.D. thesis on this topic.

Max Warburton and Mari Sako are also planning a paper on a separate financing issue. It is becoming apparent that the demands placed on suppliers by OEMs are contrary to the financial reporting ideals of the former. The pricing arrangements typically negotiated permit only the smallest of margins on bought-in parts, so while revenue rises for modular suppliers, operating profit margins fall. Board reluctance to compromise average margins may hinder divisional operations from winning modular business. In our interviews, several suppliers conceded that they are facing this problem of margin dilution.

We are insuring a tight link between the modularization research and the International Assembly Plant Study by designing questions for the Round 3 survey that will gather data on how the division of labor between the assembly plant and upstream suppliers is handled for instrument panels and door inners. The Round 3 survey will be distributed to the international sample in June; a separate report is being submitted on that project. Our experience with these questions will help us as we design a specific survey on modularization, for what we see as Phase 2 of this project (see below).

The research team has also undertaken a number of other activities in connection with this project. We have gathered relevant background materials from the academic literature, including the manuscript of a forthcoming book by Profs. Baldwin and Clark at Harvard Business School on modularization. We have also been fortunate to have access to studies of modularization carried out

by IMVP sponsor McKinsey and Company. We are actively collecting other resource materials of this kind during our company visits. We are also collecting materials about the union position on outsourcing and modularization in various countries, which will help in our effort to draw out the labor relations and human resource management implications of these trends.

We are also working to develop better ways to conceptualize what is happening with modularization. Profs. Sako and Murray are preparing a conceptual paper that reviews the literature on modularization, proposes definitions for three arenas of modularization -- "modularity-in-design", "modularity-in-use", and "modularity in production" -- and discusses how these three are interrelated. In addition, Prof. Murray is working on a model to optimize the boundaries of a module, by considering tradeoffs and interactions among the three types of modularity. Finally, Prof. Sako is writing a paper on modularity and the implications for the boundaries of the firm. The premise of this paper is that modularization carries with it the potential for distributing design and production activities on either side of the OEM's boundary. The decision about where different activities occur will be based on pre-existing characteristics of supply chains, capital markets, and labor markets. While the OEM's organizational structure may follow the architecture of product design, with respect to whether modules are placed inside or outside of the firm boundary, the causality may also be reversed, with organizational structure influencing where the boundaries of the firm are set.

We anticipate having one or more papers from this effort available at the time of the sponsors' meeting in October 1999. These papers will also provide the basis for us to engage our academic colleagues in discussion about the conceptual issues around modularization and outsourcing.

Next Steps

We have made strong headway in every aspect of the project: developing the conceptual framework; gathering of relevant resource materials, arranging access to research sites, carrying out field interviews. We anticipate doing a substantial number of additional field visits this summer. As mentioned above, we will place a higher priority on doing interviews with suppliers in the upcoming phase.

For the sponsors' meeting in September, we would like the opportunity to present our project in three discrete parts, each involving presentations from different members of the research team:

1) Conceptual: Here we would draw on the papers being prepared by Profs. Sako and Scott-Murray, including the literature review and definition of terms; the model for optimizing the boundary of a module; and the analysis of the implications for the boundary of the firm.

2) Field Work: Here we would summarize what we have learned from field work in the U.S., Europe, and Japan.

3) Implications: Here we would sketch 3-5 possible scenarios for how modularization and outsourcing trends will develop in the future, taking care to focus on the implications for OEMs; suppliers, capital markets; and labor markets.

If we think of this period of doing interviews at OEMs and suppliers as Phase 1, we anticipate that Phase 1 activities will need to continue into the next fiscal year. We are finding a much higher level of interest than we expected, and arranging access at some many different companies has taken some time. However, the cooperation we are receiving at most (but not all) of our field sites is encouraging and we expect that the field visits will be easier to set up over time. We are also working out arrangements with the companies so that the researchers can contact individuals directly for follow-up information (by e-mail or fax) rather than having to work through the liaison person at all times.

Phase 2, as mentioned above, would take what we have learned about modularization and outsourcing, both from our field work and from the conceptual work, and develop a survey that could be distributed widely to collect systematic data. The survey will cover both strategic issues and a host of specific issues related to the modules we've chosen as our case studies. (We may examine additional modules as well.) The research team plans an initial meeting about the survey design in connection with the IMVP sponsors' meeting in the fall. Meanwhile, certain activities will span the two phases, including Fiona Murray's modeling work on the optimization of modular boundaries, Mari Sako's conceptual work on the impact of modularization on the boundaries of the firm, and Max Warburtons project on margin dilution.