Multimedia Platform Framework for the Automobile: Architectural Analysis and Proposal Evaluation

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Abstract

The automobile industry is at a critical point in the development of in-vehicle entertainment and information features. The consumer electronics industry is changing dramatically in the areas of entertainment through audio and video playback, personal efficiency tools, and wireless communications. Equally as significant is the rapid development and feature migration that is occurring between four of the major mobile device categories; mobile phones, smart phones, PDA's, and media players. With this convergence occurring, automakers are finding it more difficult to satisfy the needs of consumers with respect to these new capabilities.

In order for the automakers to establish a solution, a new framework needs to be established. The automakers are unable to satisfy this market desire through traditional technology delivery strategies, especially given the fast changing and complex interface that currently exists in this market space.

This thesis establishes the framework used to identify and critically evaluate an external platform strategy for the purpose of satisfying the above need. The thesis draws upon leading literature to provide key attributes of successful external platform implementations. The first aspect of the framework established involves ensuring the need for an external platform through complexity and development clockspeed incompatibilities. The second section of the framework involves the evaluation of the architectural attributes that lead to external platform success. Finally, the stakeholders are identified and roles are established.

The next phase of the analysis involves the evaluation of two prominent solution proposals using the established framework. These include the standards-based solution model that was developed at Automotive Multimedia Interface Collaboration (AMI-C), and the more recent commercial operating system proposal. These proposals are evaluated to determine if a specific proposal is better suited to capture the mobility market interface in the automobile than another. The analysis and framework provided it this thesis provides a basis for further tactical evaluation by the automakers that wish to meet the needs of the mobility market.

Thesis Supervisor: **Professor Michael Cusumano**
Title: **Sloan Management Review Professor of Management**

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Jonathan Baughey	my son, my buddy
Parker Baughey	my son, my baby
Judy Baughey	my mother, my confidence
Grant Baughey	my father, my strength
Louise Brown	my mother-in-law, my security
Denver Brown	my father-in-law, my perspective
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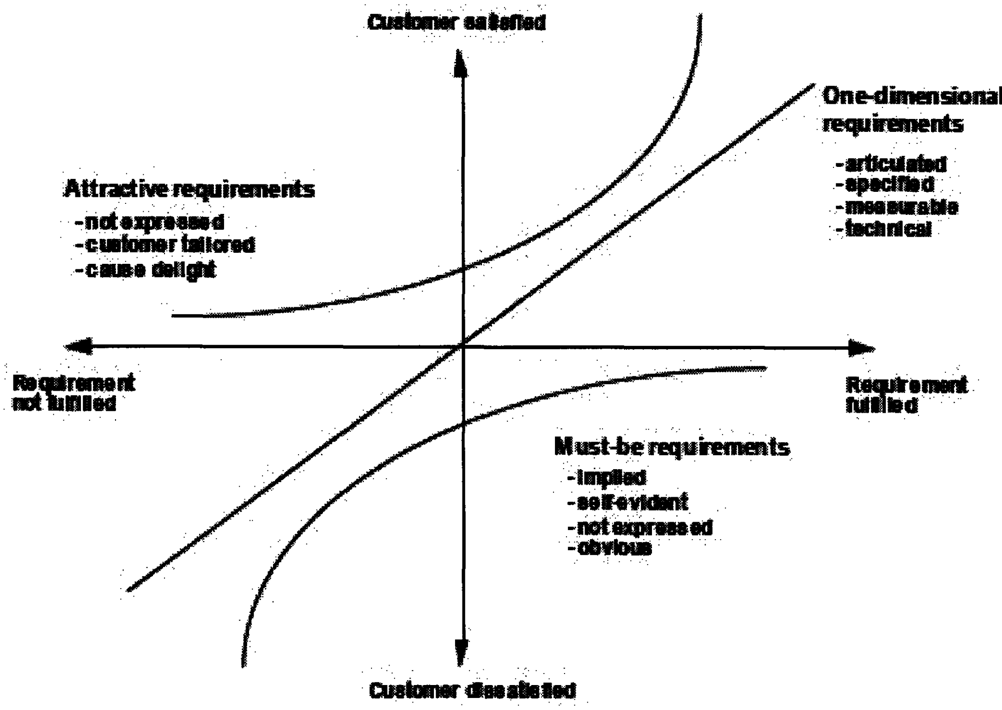
1 Introduction

The automotive industry is experiencing tremendous competitive pressure. Markets across the world are growing more and more competitive due in large part to the many entrants that have emerged over the past two decades. No longer are market segments like trucks, SUV's, and small passenger cars dominated by certain companies, like the American, European, and Asian firms. Today, firms compete everywhere, both geographically and within product segments. To grow, an automaker must go above and beyond just basic needs. Sustainability means creating something that customers must have, something that affects more than just transportation, something that improves their lives. This paper provides a framework for identifying the opportunity and addressing proposed solutions.

1.1 Motivation

Many people in the auto industry talk about the migration of product technologies from surprise and delights, to customer wants, and finally to basic needs over time. This concept is illustrated in the common Kano-model that is shown in Figure 1-1 below. The migration of a given feature typically moves from the upper-left quadrant to the lower-right over time. What was once a feature that enticed the buyer to purchase a given vehicle is now an expectation or the price of entry. However, the vehicle itself is rapidly becoming the basic expectation. Competition has become fierce, overproduction is common, and product offerings are enormous. What automakers need is a way to change the customer's experience with the vehicle, a way to truly improve the customer's life by enabling them to become more efficient and entertained while executing the task of transporting themselves from one point to another.

Figure 1-1: Kano Model



Source: Sauerwein et al, 1996, pp. 2

One way for this to happen is to extend the vehicle beyond the bounds of automotive transportation and becoming as integrated as the rest of the consumer world. The consumer electronics field has long been discussing "convergence." This involves the combining of features and functions into a device architecture that is enabled by continual technological evolution in the electronics and software industry. The question isn't if convergence is happening, it is how the converged architecture will look when the consumer electronic feature integration settles down.

There are several indications of feature integration and movement between different mobile device product categories. For instance, phones have introduced camera functionality, and now media streaming. Media players have introduced synchronization capabilities that provide calendar features, and are even rumored to be integrating phone functionality. Likewise, phones have migrated into the PDA market by introducing an operating system architecture allowing them to run complex applications, and PDA's have entered the phone market by introducing wireless connections. This convergence and feature expansion provides the automakers with a significant opportunity to enhance these products in an environment that is used over 500 million hours per week in the United States. (Light, 2002)

This notion is not a new one by any means. In fact, the attempt to step into this market has been seriously discussed for at least the last 10 years. There are numerous attempts to connect to this market including some of the more recent connection systems like Bluetooth and iPod connections. There are many automakers that offer these features, with enhanced command and control of the consumer electronic device using the vehicle's interfaces. However, there are a couple of limitations that exist. The first of these limitations is the bounded scope of the connection. For instance, the iPod connection systems that are in place are exactly that, iPod connection systems. Although iPod does command a significant portion of the market, they don't command all of it, there are many other players out there. In fact, other players that are supporting different features like subscription music services, features that iPod doesn't offer. As fast as the market moves, it is potentially dangerous to lock into a particular connection that is specific to one product or architecture. This is especially important since the automakers exert very little control over the market. Similarly, Bluetooth has proliferated itself as a connection system standard for mobile phones and their accessories. However, what would happen if a significant shift happened in the consumer market, and the automakers were forced to cycle in a new technology among its dozens of product offerings over a period of 4 years? At the end of that 4 years, the next new technology could have emerged.

So if more aggressive plans are needed to corral the consumer mobility market into working with the automotive market, how is a given strategy developed and critically evaluated to ensure that it possesses the strategic ability to shift multiple markets? How does a firm that is currently an outsider looking in, harness the capabilities of a market that is changing extremely fast, especially when its own market is under intense competitive pressures? It is much like standing on the banks of a river that is flowing wildly. The need is to connect with the other side, without getting caught in the rolling water, overcommitted and unable to move.

This paper provides insight through architectural framework development, and then provides application of the framework to two leading solution proposals. The first proposal is the standards based approach that was lead by industry groups in the late 1990's, including the most prominent Automotive Multimedia Interface Collaboration (AMI-C). The second is a fairly new initiative that is being proposed by Microsoft's Automotive Business Unit, the introduction of a commercial operating system into the vehicle architecture. The purpose of each is to provide standard interfaces and application capability. The intention is to learn from the past, to critically evaluate new proposals, and potentially shape new solutions for the future.

1.2 Scope

As mentioned above, this paper is meant to provide a strategic framework for critically evaluating solutions to the convergence of the consumer electronics mobility market and the automotive markets. As such, the scope of the paper includes the interaction of these parties, along with the major stakeholders that drive them. Although the framework has the potential of extensibility beyond these markets, the paper does not attempt to broaden the product market scope mentioned.

In addition to the product or market scope, the scope of the paper's analysis involves a strategic look at the solution space. The intent is not to prove that one solution is better than another, but it is meant to illustrate the mechanics of a framework, by applying it first to the current solution (standards-based approach), then to a proposed solution (commercial operating system). Applying the framework in this way will illustrate the risks and benefits of each, and ultimately allow the user to develop alternative scenarios to mitigate specific drawbacks.

1.3 Methods

The primary method used in the thesis is the literature review in several of the key areas being addressed. Specifically, the leading publications in the area of platform creation and management are used to establish the benefits and drawbacks of the proposed platform solutions. More importantly, these publications are used to develop a generic framework for subsequent analysis. The intention is to critically evaluate the attributes of a solution with respect to platform strategy.

Next, product architecture publications are reviewed to establish appropriate characterization of platform-based architectures. The intention of this review is to provide the reader with a way to critically evaluate a proposed solution determining if the strategy is addressing the need.

Finally, the established framework from the literature review is applied to the leading solutions in automotive connectivity. Data is gathered in several key areas including market conditions, architectural abstractions, and final performance. Market conditions are gathered through publicly available research databases and articles. Architectural analysis is conducted through publications on the specific topics and interviews with parties that were involved in the strategy. The overall performance was evaluated through market data, publications, and personal interviews.

1.4 Report Flow

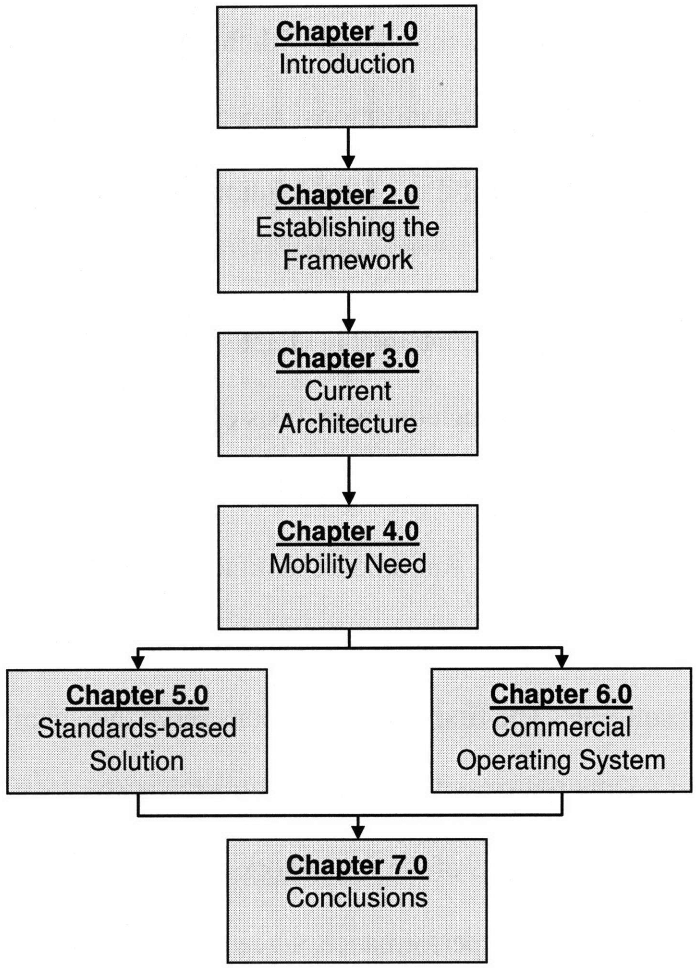
The report is broken up into two main sections. The first section establishes the framework for critically evaluating the proposals. The second section applies the framework in order to determine the appropriateness of the given solutions. Finally, the framework and results are summarized in the conclusion section of the paper.

The first section referenced above involves developing the framework that is used for further analysis. This framework is completely developed in chapter 2 of the paper. This chapter starts with establishing a taxonomy that is used throughout subsequent chapters of the paper. Next, the methods for evaluating the specific needs that are being addressed are covered. After this, the architectural framework is introduced with the specific attributes appropriate for platform implementations. Finally, the organizational aspects of platform creation in this context are established to determine the sustainability of the solution.

The second section of the paper contained in chapters 3 through 6, applies the framework established above. These applications include an analysis of the existing multimedia connectivity architecture. The second involves a prominent solution that has been supported by many of the leading automotive original equipment manufacturers (OEM's). Finally, the proposed commercial operating system solution is evaluated in order to determine the specific risks and benefits of the solution. The first two applications serve two main purposes within the paper. First, they show how the framework should be applied to a given solution, and secondly they provide a proof of the effectiveness of the framework application. These solutions can be evaluated based on the existing market performance, since they are already implemented, or are ready for implementation. The third application to commercial operating systems provides insight into the future.

The following figure illustrates the flow of the report.

Figure 1-2: Report Flow



2 Setting the Stage: Platform Taxonomy

The concept of product platforms has been proliferated over the past several decades. In fact vast amounts of research and publications have been created regarding what platforms consist of and what advantages can be had with the adoption of this strategy. However, the implementation of the platform strategy can have very difference characteristics depending on its location within the system, as well as the driving forces behind it. The following chapter starts by providing platform definitions for the purpose of clarifying the context of this paper's analysis. Next, the architectural implications associated with certain strategies are summarized, providing a framework for architectural analysis relative to the adoption creation of an interface solution between dynamic industries. Finally, the roles that platform stakeholders have within the architecture are evaluated to gain a better understanding of the enterprise implications with the adoption of platform architectures. This illustrates the framework for future evaluation of mobile market platforms in automotive electronics.

2.1 Platform Definition

As indicated above, platforms in one form or another are described and analyzed extensively in the management and engineering forums. One of the broadest definitions of platforms describes them as:

> *"a collection of assets that are shared by a set of products with the following four viewpoints 1) components 2) processes 3) knowledge 4) people and relationships."*
>
> *(Hodges, 2004)*

The key word in this definition is "shared" indicating the common point between the "assets." In other words, the critical function of the platform becomes the interfaces that are created between the elements of the system.

More common definitions of platforms focus on the product and process decomposition of product platform commonality (Hodges, 2004). A product platform is defined as:

"A set of common components, modules, or parts from which a stream of derivative products can be efficiently created and launched"

(Meyer and Lehnerd 1997)

In this case, the scope of the platform is limited to the form viewpoint, indicating a physical part focus. Platforms are commonly centered on the physical architecture of a product, therefore this definition has become viewpoint that many technical professionals take when discussing platform strategy. For instance, automotive platforms are typically described by the chassis and powertrain combinations from which the body and trim structures are attached. Similarly, airframe structures in commercial aircraft can be thought of as platforms. On a smaller scale, Black and Decker created platforms around the motor structures of the electric power tools, allowing for multiple variations to be created from the base unit (Meyer and Lehnerd 1997).

The point of the above summary is to illustrate the scope of the term platform by the market. In the broadest sense, platforms include everything from parts to people and knowledge. In the narrowest sense they typically include specific products or specifications defining these products. These definitions provide a good set of guidelines for describing the components that make up a platform, but lack the variation in platforms with respect to firms and stakeholders. An important attribute that should be taken into consideration when describing a platform is the relative position within the firm, the industry, and the market. For the purpose of this paper the term *product platform* will be used to describe platform components that lie within a firm. In contrast, the focus of this paper will be on *external platforms* that lie at the boundary of the firm, for the purpose of providing external interface to other stakeholders in the market. Recognizing this distinction becomes critical in resolving the interface issue facing automakers in this market. This is described further in section 2.2.1 when customer needs are discussed.

2.2 Platform Drivers: Needs and Costs

The next aspect of the platform framework involves determining what conditions drive platform generation. This will set up the framework for evaluating the appropriateness of platform creation or investigation. As with any technical initiative, platform creation absorbs resources from the platform leader and the affected stakeholders. For this reason, the need or trade-off should be understood before executing a platform strategy, determining the appropriateness of the platform creation. The absence of a well defined need statement will reduce or eliminate the effectiveness of the platform solution. Typical platform needs are based on the advantages that can be achieved through their creation. In an SAE article in which Hodges investigated the effects of platform creation in the automotive industry, he summarized the advantages and disadvantages of platforms based on some of the leading publications in the field. The results are shown in the following Figure.

Table 2-1: Platform Benefits and Risks

	Robertson and Ulrich [57]	Siddique et al. [61]	Muffatto [48]	Muffatto and Roveda [49]	Nelson et al. [50]	Reimpell et al. [56]	Upham [78]
Advantages							
Reduced development time	x	x	x	x	x	x	
Reduced development cost	x	x	x	x		x	
Reduced complexity	x	x	x	x			
Tailor products to market segments/increased design flexibility/variety	x	x			x		
Improved learning across projects/experience with complex functions			x	x		x	
Reduced manufacturing cost	x	x					
Increased reliability			x	x			
Reduced production investment	x						
Reduced parts count		x					
Reduce manufacturing facilities, tools, and processes					x		
Reduced inventory					x		
Re-use of some engineering analyses						x	
Lower risk	x						
Improved service	x						
Disadvantages							
The erosion of brand differentiation					x		x
Internal conflict over distinctiveness/commonality (marketing versus engineering)	x						
The effort required to prevent impasses over details.	x						
Common requires design for the most severe duty cycle					x		
Difficult to implement when architectural complexity is high.				x			
Product architecture can impose severe constraints on the platform's definition.				x			

Source: Hodges 2004, pp. 6

It is clear from the summary that platforms can improve many of the performance metrics related to delivering innovative products to market, including reduced development time, reduced complexity, improved reliability, etc. In addition, producer benefits are also significant by providing lower development costs, lower manufacturing costs, and decreased complexity. However, to illustrate the potential disadvantages that stakeholders can be faced with, the bottom half of the figure should be examined closer. This section of the chart indicates that platform creation can cause issues with maintaining brand differentiation, difficulty in resolving technical issues, reduction in functional performance due to limitations of the platform, etc. From this viewpoint, platforms can be considered an investment, with costs as well as benefits. For this reason, the decision to implement a platform strategy should be deliberate and planned. The firm should be aware that costs will be incurred, costs that should be offset by advantages to make the endeavor worthwhile.

In addition to the disadvantages described above, there are similar issues with external boundaries in terms of intellectual property ownership. A common theme described in many of the Platform Leadership cases involve resolving issues created by proprietary versus open platform creation (Gawer and Cusumano, 2002). These disadvantages further illustrate that platform creation is not a free activity. Client needs must be fulfilled and stakeholder value must be created to make the incorporation of the platform justified. The following section describes some of the most common factors that indicate the need for a platform solution.

2.2.1 Satisfying Customer Needs

The first step in the process of this paper's analysis is establishing the need of the client that justifies the incorporating of the interface. This seems like a trivial step, but the step is critical in establishing the driver for the development effort. In the case of *product platforms*, where platforms are created within product systems, the likely need from the customer is the lower cost and faster development cycle that can be achieved. For instance, the case of Black and Decker's use of common internal components provides a good illustration of this fulfillment. With common internal components that are scalable based on the target market, the customer is provided a variation of products that can be fit to a given level of skill and capability. This provides the customer with the ability to choose the product that best fits their needs, including performance, function, and cost. This need fulfillment allowed Black and Decker to justify the added investment required to produce the new design (Meyer and Lehnerd, 1997).

Table 2-2: Black and Decker Platform Performance

	Old Design and Manufacturing Process	New Design and Manufacturing Process	Improvement
Operators to produce	108	16	85%
Cost to insulate (materials, labor, overhead)	$0.51	$0.31	39%
Labor cost/unit	$0.14	$0.02	85%
Capital to produce	$400,000	$1,222,000	
Annual savings (labor and material)		$1,280,000	

Source: Meyer and Lehnerd, 1997, pp. 10

The satisfaction of external customer needs become evident through the increased product market shares enabled through price reductions and additional product offerings. Again, these benefits were enabled by the creation of the internal *product platform.* These internal platforms are usually driven by internal client's needs. As indicated in Meyer and Lehnerd's book, the start of the product platform creation at Black & Decker began with the regulatory initiative that forced Black and Decker to redesign the core of its product (Meyer and Lehnerd, 1997). In other words, the customer need in this case was the government agency requiring the design change. The market benefits were emergent relative to existing costs pressures and rising concerns by regulators regarding product safety.

In contrast to internal *product platforms* described above, external customer needs must sometimes be satisfied by creating platform boundaries at the edge of the system or firm. This *external platform* creation allows for integration of other systems that complement the existing system. A good example of this is the advent of the Universal Serial Bus (USB) standard that made possible the connections to the personal computer by other systems and components that were not originally associated with the computer. The creation of the USB standard sparked computer peripheral suppliers to adopt the standard, increasing the capabilities of the system. In time, even more diverse product categories started using the interface to connect to the PC such as MP3 players and digital cameras. The device performance and capabilities are complemented by the easy connection to the personal computer. This external platform interface provides the customer with the direct value of increased performance and function through product system interaction.

2.2.2 Clockspeed Boundaries

The first driver for platform creation that usually comes to mind involves the insulation of clockspeed boundaries that exist between interfacing assets. Nathan Everett used the term "*clockspeed collision boundary*" to indicate the boundary between products that evolve at different rates (Everett 2003) in the paper "Automotive Telematics: Colliding Clockspeeds and Product Architecture Strategy." This concept was based on Dr. Charles Fine's book "Clock Speed: Winning Industry Control in the Age of Temporary Advantage." This book identifies the differing rates among firms and industries with respect to product, process, and organizational change cycles. Everett proposes that modularity along the boundary of the *clockspeed collision boundary* can decouple the innovation cycles and allow both sides to operate efficiently while solving the needs of the end consumer. This essentially describes *external platform* creation.

This clockspeed collision boundary concept is illustrated by the advent of the PCI bus interface by Intel. The PCI bus was developed to decouple the performance of the personal computer microprocessor from the rest of the computer architecture. It consists of the communication system between the micro and the peripheral components that rely on the microprocessor. Intel was able to use the development of this PCI bus platform to insulate the computer from the technological advances of the Intel microprocessor. Because of this, Intel was able to rapidly improve the performance of the personal computer and enable the overall system to meet more consumer needs. The bus platform that was central to the "Wintel" architecture allowed Intel to be the premier provider of microprocessors in the growing personal computer market. The strategy was based on the need for Intel to decouple themselves from the rest of the computer, allowing them to rapidly advance the technology. This in turn allowed them to fuel increased market demand by enabling new products to be created based on the increase in performance.

In Fine's book he contends that industries and products evolve at different rates (Fine, 1998). The following table from the book shows the comparison of different technologies and the rates of development in terms of product, process, and manufacturing. When significant interaction is needed between components that evolve at different rates, clockspeed collision boundaries are formed. These boundaries create significant coordination efforts for the firms on each side of the layer. These firms must coordinate each release cycle with each other. The faster evolving component must either wait for the slower product to catch up, or must design new products to an old interface, often time sacrificing performance. Several segments are illustrated in the figure below. An example of this concept is evident in the PCI case described above. The Intel chips were able to advance in terms of speed and performance much faster than the traditional PC bus that they were connected to. They were forced with the decision to develop product to connect to a sub-standard bus (sacrificing speed), or create an interface layer that was capable and flexible enough to grow with them.

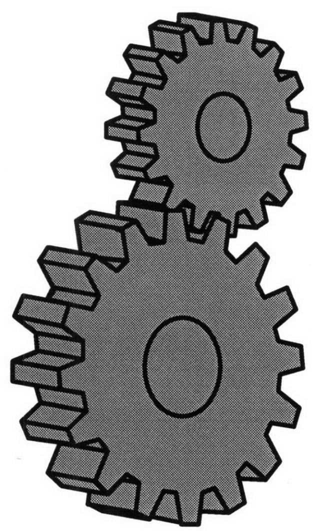
Table 2-3: Industry Clockspeeds

Industry	Product Tech Clockspeed	Process Tech Clockspeed	Organization Clockspeed
FAST CLOCKSPEED INDUSTRIES			
Personal Computers	<6 months	2-4 years	2-4 years
Computer-aided software engineering	6 months	2-4 years	2-4 years
Toys and games	< one year	5-15 years	5-15 years
Athletic footwear	< one year	5-15 years	5-15 years
Semiconductors	1-2 years	2-3 years	3-10 years
Cosmetics	2-3 years	5-10 years	10-20 years
MEDIUM CLOCKSPEED INDUSTRIES			
Bicycles	4-6 years	10-15 years	20-25 years
Automobiles	4-6 years	4-6 years	10-15 years
Computer operating systems	5-10 years	5-10 years	5-10 years
Agriculture	3-8 years	5-10 years	8-10 years
Fast food	3-8 years	25-50 years	5-25 years
Beer brewing	4-6 years	400 years	2-3 years
Airlines	5-7 years	25 years (hardware) 2-3 years (software)	<5 years
Machine tools	6-10 years	6-10 years	10-15 years
Pharmaceuticals	7-15 years	10-20 years	5-10 years
SLOW CLOCKSPEED INDUSTRIES			
Aircraft (commercial)	10-20 years	5-30 years	20-30 years
Tobacco	1-2 years	20-30 years	20-30 years
Steel	20-40 years	10-20 years	50-100 years
Aircraft (military)	20-30 years	5-30 years	2-3 years
Shipbuilding	25-35 years	5-30 years	10-30 years
Petrochemicals	10-20 years	20-40 years	20-40 years
Paper	10-20 years	20-40 years	20-40 years
Electricity	100 years	25-50 years	50-75 years
Diamond mining	Centuries	20-30 years	50-100 years

Source: Fine, 1998, pp. 239

The following figure provides an analogy to understand the implications of different clockspeeds. In this case there are a set of gears with different diameters that are engaged. In this arrangement the smaller gear makes more revolutions compared with the larger gear. If the larger gear makes one complete cycle, the smaller gear will make more than one cycle depending on the difference in gear diameters, or the gear ratio. In this analogy one can consider the cycle of a gear synonymous with the cycle through a product development cycle, going from concept, design, verification, and production launch. Therefore, as the two gears cycle through the contact points become out of cycle. Even if the product launches are at the same time during the first cycle, they will be out of cycle on the next round.

Figure 2-1: Clockspeed Analogy – Gear Ratios



2.2.3 Complexity

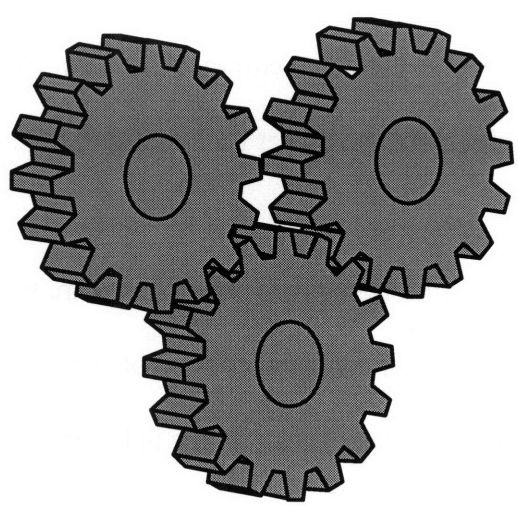
The next driver that this paper examines justifying the use of product platforms through the existence of design complexity at the interface. Design complexity at an interface can have the same effect as clockspeed collision boundaries in that design trade-offs and coordination efforts must be undertaken to achieve compatibility. Coordination efforts can become very costly to maintain. If coordination efforts can not be effectively maintained, interface incompatibilities will exist, or performance loss will be exhibited in terms of reduced levels of interaction.

This is seen in the Black & Decker case from section 2.2.1 (Meyer and Lehnerd, 1997). Although the platform creation was driven by external regulatory concerns, the overall performance increases were achieved by increasing the efficiency of the internal systems. This efficiency gain was achieved by reducing the complexity needed to accommodate the complexity of the external market. The different functional needs of the customer were served by creating unique power tool designs which all performed the same basic function, taking electrical power and converting to mechanical power via an electric motor. Then using the motor output to manipulate building materials according to the needs of the customer (performance and configuration). Black and Decker created a common parts platform to insulate the core components from the complexity of the power tool configurations.

Without a platform definition, the core components are faced with coordinating a common design to meet the needs of each and every tool configuration, or create custom designs for each configuration. In the first case, the outcome is likely a motor design that is under designed for some configurations and over designed for others. The outcome of the second is the current state of the Black and Decker product line before the regulatory issue. The cost and business structure to maintain the individual tool configurations utilize resources inefficiently by duplicating investment efforts, engineering efforts, and manufacturing efforts. Black and Decker solved a complexity issue by creating a scalable platform design for the core components that could be designed around during the tool configuration design.

Now the same analogy presented in the previous section is used for the complexity condition described above. In the following figure equally sized gears are mated, but there are multiple gears engaged at the same time. In this case, the gears could theoretically be synchronized, providing product launches at the same point for each revolution. However, the likelihood that multiple gears would be perfectly matched is very low. The effort to start them in a synchronized manner is very large. Even if they were synchronized at the start, real firms and industries vary over time effectively changing the diameter of the gear over time.

Figure 2-2: Complexity Analogy – Multiple Mating Gears



2.3 Architectural Analysis

Establishing the need is a critical first step in designing any system, regardless of whether platforms are involved. The creation or identification of a platform in any product system should actually be the outcome of an architectural analysis that is conducted with respect to the specific needs of the stakeholders. For this reason, architectural analysis becomes a critical part of the platform evaluation used in this paper. Once the needs are established, the product architecture is developed or described for the purpose of further evaluation of the stakeholder roles.

The critical steps in developing the architectural framework for the platform is determining the appropriate domain space for the product system, decomposing the system using an appropriate viewpoint, and finally clearly identifying the presence of the platform. The domain space determines the high-level structure of the product system, or the way in which the product systems interact. The viewpoint or decomposition determines the way in which the product system is described or broken down. The presence of the platform is based on a framework described in the following sections.

2.3.1 Relevant Architectural Domain Space

The primary stakeholders in the case of platform development can be internal, external, or a combination of the two with respect to the product system boundary. Internal stakeholder's needs would likely involve improved delivery of a product by decreasing costs, decreasing delivery time, or expanding available products. These improvements benefit the external stakeholders through secondary improvements like lower cost, higher degree of product customization, or increased performance improvement, but the interface created for the platform is not likely to benefit them directly.

In summary, platforms are the result of stakeholder needs, whether internal or external stakeholders. The relative location of the main stakeholder provides an indication of whether the platform creates a *product platform* or an *external platform* interface. The example of the Black and Decker development described above is a good example of a product platform that directly benefited components within the system. The interface that was created allowed for cost and performance increases in the power tool market, but the parts at the interface did not directly interface with the customers or components on the outside of the system.

Maier and Rechtin provide a good list of domain space options that should be considered when architecting product systems (Maier and Rechtin, 2002). These include the following:

- **Builder architected systems** – Consist of a design-first approach in which the form is already established before the need is identified.
- **Collaborative systems** – Consist of a system-of-systems design in which independent systems interact in a larger system.
- **Manufacturing systems** – Consist of process designs for efficiently transforming products in over time.
- **Social systems** – Consist of product systems largely involve interaction with large groups of people as a core function.

- **Information technology and software systems** – Consist of systems that rely heavily on software collateral as the core of the design. The reason for the separate classification is the uniqueness of software as a product.

The relevant domain in the context of this paper is the collaborative systems model. Builder architected systems refer to a system that is under *central control* with the builder of the system making all design decisions, often without specific input from the client being served. It will be shown that using this model to architect a system that actually fits a collaborative model can result in poor performance. Manufacturing and social systems are not considered for obvious reasons. Information technology and software systems are not included due to the fraction of the architecture that actually involves software. Although, the paper considers the operating system as a platform, the systems considered from here on consist of many components that are multidisciplinary.

2.3.2 Relevant Architectural Viewpoints

The next architectural analysis involves the decomposition of the proposed system into elements and interfaces. The structure of the system will be determined by the viewpoint taken during the decomposition. Maier and Rechtin provide some insight into common decomposition strategies using the following table.

Table 2-4: Architectural Viewpoints

Perspective or View	Description
Purpose/Objective	What the client wants
Form	What the system is
Behavior or Function	What the system does
Performance Objectives or Requirements	How effectively the system does it
Data	The information retained in the system and its interrelationships
Managerial	The process by which the system is constructed and managed

Source: Maier and Rechtin, 2002, pp. 146

The scope of this paper revolves around the translation of function to form. The need is first established by determining the functional desire of the customer. This need is translated into the needed sub-functions. Once these sub-functions have been established through the functional decomposition, the form decomposition is established for the proposals evaluated. The other decompositional models provided in the table are related to the performance of the system, or the tactical implementation of the system as it is designed. For this paper it is assumed that these models will be emergent from the design, or they will be a secondary design activity based on the desired tactics of the stakeholders.

2.3.3 Valid External Platform Architecture

Once the functional and form decompositions have been established, the system design is evaluated to determine fit with the external platform strategy. In order to determine whether a given design fits the model that is being targeted, the design must be evaluated based on some criteria, which in turn is based on relevant platform definitions. The following is a list of three attributes which are important in the creation of a mobility platform between the consumer electronics market and the vehicle market. These were compiled based on investigation of leading publications on the design and implementation of platform strategies. The inclusion of certain attributes was based on the desire to evaluate a strategy within the context of external platform creation, using a system-of-systems viewpoint. In other words, the overall goal of creating a common interface for independent consumer products is kept in mind when selecting the appropriate platform definitions.

- Common interface specification ... modular interface boundary from which a stream of derivative products can be developed. (Meyer and Lehnerd, 1997)
- Part of a system that is continually changing. (Gawer and Cusumano, 2002)
- Architecture is viewed as a collaborative system with participation from all assets and focus on the interfaces. Clients are decentralized with choices to participate or not. (Maier and Rechtin, 2002)

2.4 Platform Stakeholder Roles: Leaders and Complementors

Once the external platform has been established, the stakeholder roles are summarized using the framework described in Platform Leadership (Gawer and Cusumano, 2002). The two primary roles described are *platform leaders* and *complementors*. Platform leaders have the role of defining the platform design and taking the actions necessary to make the platform relevant in terms of enabling complementors to fill customer needs. The "levers" that *platform leaders* must take into consideration are scope of the firm, technology, relationships with complementors, and internal organization (Gawer and Cusumano, 2002). In addition, two specific properties regarding the system and the platform are identified in order to make the creation of the platform a valid business. The property of the system in which the platform exists is that is should be continuously evolving. This property is established as part of the architectural analysis and clockspeed analysis previously described. The property of the platform within the system is that it has no independent value outside of the existence of derivative or complementary products. This property is evaluated as part of the stakeholder roles of the platform leader. This independence criterion is a very important attribute in determining the relevance the external platform given the complexity and clockspeed drivers.

On the other side, complementors have the role of supporting the platform by innovating at the platform interface to create value for the customer. These complementors become critical in justifying platform creation since the platform itself has no value without complementary assets. For the purpose of this paper we will be reversing the Platform Leadership lens and looking the platform implications from the complementor's side, specifically the automaker's side. This is extremely important for both parties since platform leaders need complementors to proliferate the platform, and complementors can identify the opportunity to innovate and create value. Therefore, complementors can create value by identifying relevant platform trends and positioning themselves as "rabbits." A "rabbit" is a term used in Gawer and Cusumano's Platform Leadership to represent a "shining example" as quoted in the book by Miller from Intel. In other words it is a complementor that steps out and takes the risk of adopting and innovating on a new platform strategy. However, the risk is high if a complementor doesn't properly evaluate the need, architectural position, and stakeholder roles. Adopting a platform architecture that doesn't come to fruition can result in wasted development effort and unsatisfied customers.

This is particularly valid in industries with slow development clockspeeds like the automotive industry.

3 Establishing the Baseline: Current Multimedia Platforms

This section utilizes the framework described above to illustrate the current automotive multimedia system and its interfaces with the consumer. The intent is to use the definitions and framework described above to evaluate the current automotive multimedia platform, establishing the baseline analysis from which the next two examples will be built. This will aid in the analysis done further in the paper, and provide an example of the framework application.

3.1 Customer Needs and Current Automotive Multimedia Systems

The current multimedia system in the automotive industry involves supporting various forms of consumer media for the purpose of entertainment and information playback. This boundary lies directly between the consumer media that is brought into the vehicle and the interface at the various multimedia electronics modules installed in the vehicle. The media that customers bring into vehicles consist of many formats including AM/FM radio signals, cassette tapes, compact discs, DVD's, portable media players. These media formats can be thought of as platforms for media storage and delivery that were generated outside of the automotive industry. In order to serve the customer's established need for in-vehicle entertainment, the automakers have chosen to incorporate support of these media formats into the vehicle architecture.

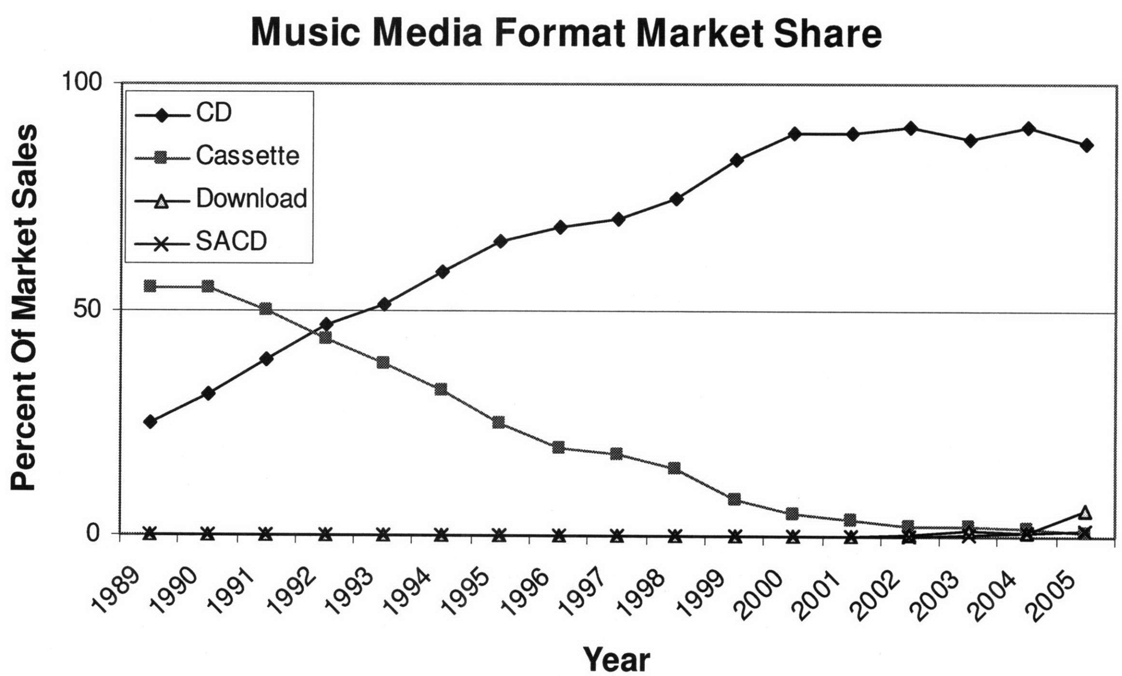
It is probably worth noting that the need identified above was found by working backward through the process. In the ideal case, the need would be established by working with the customer and analyzing market trends and data. However, in this case the need was identified by examining the current product offerings. This is appropriate for the purpose of this analysis since the product offering has been established for a long time. CD's have been around for years, and cassette tapes for decades. This stability in the product offering indicates that the need has been satisfied through the product. Had the current product offering been around for just a short period, it would be plausible that the need could not be confidently established by working backward in this manner.

3.2 Current Automotive Multimedia System Clockspeed and Complexity Analysis

This section starts with the analysis of the clockspeed differences exhibited in the current automotive multimedia system. The first industry segment considered in this analysis is the automotive development cycle. Charles Fine's book indicated that the product clockspeed of the automobile was between four and six years (Fine, 1998). However, the data was gathered in 1998. Automakers have made significant strides is reducing new model introduction times to between two and four years (Hodges, 2004). This figure represents a large customer perceivable change. The actual underlying architecture clockspeed is probably longer but the opportunity to adjust comes every 2-4 years.

Next, the clockspeed of the media platform is established and illustrated in the following figure. It can be seen that the creation and stabilization of the media format allows for innovation at the consumer electronic side of the boundary and at the automotive side. Vehicle interfaces have been able to improve the media experience by providing additional features like the migration from single CD audio heads, to 6-disc CD changers, to in-dash CD changers. The chart indicates a development clockspeed in media format that is slower than that of the automobile. In fact, the chart seems to indicate a clockspeed of about 20-40 years with a product overlap of about 10-20 years. This makes it possible for the automaker to design and implement devices for media interaction that serve the needs of the customer over the useful life of the vehicle.

Figure 3-1: Media Format Migration

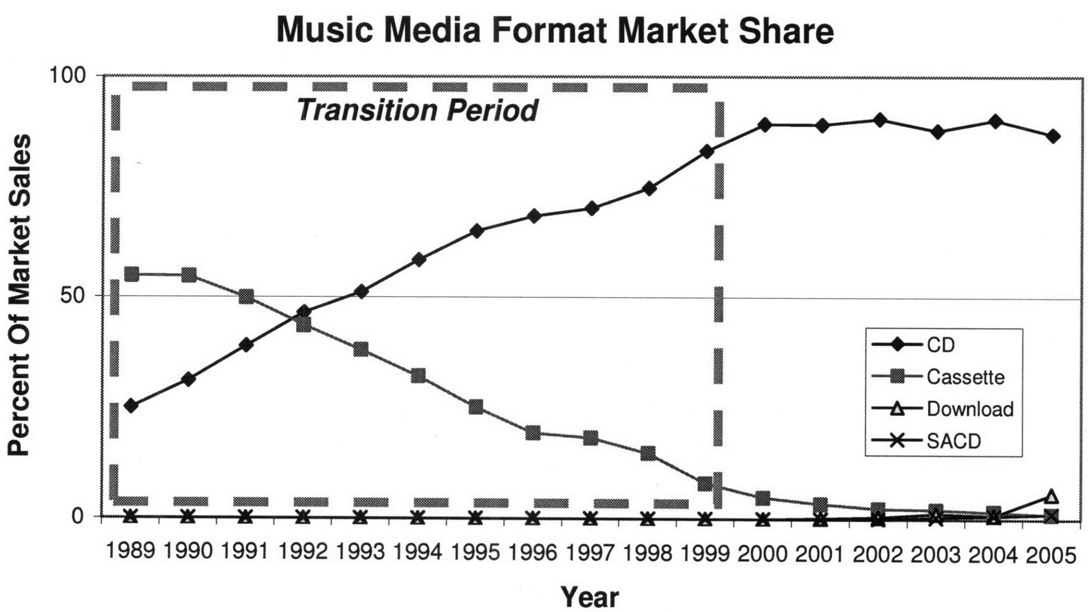


Source: RIAA 1998, RIAA 2006

Complexity in media formats is also manageable within the limitations of the vehicle configurations. First, there are only two prominent media formats in the market at any one time.

Next, the current media formats usually overlap by 10-20 years as early adopters shift to new formats and trailing users continue to use the old. This is illustrated in the shift of media offerings from cassette tapes to compact discs. Automakers are able to support both by allowing the customer to order vehicles with either media, and in some cases radio head units that support both. This period of dual offering is shown as the shaded period in the figure below. Likewise video entertainment has shifted from video cassette tapes to DVD's. However, the customer need for video entertainment on a large scale did not really accelerate until the DVD format became popular. Video cassette players were available from the automakers, but not a large scale, and largely by aftermarket means like conversion vans.

Figure 3-2: Media Format Overlap

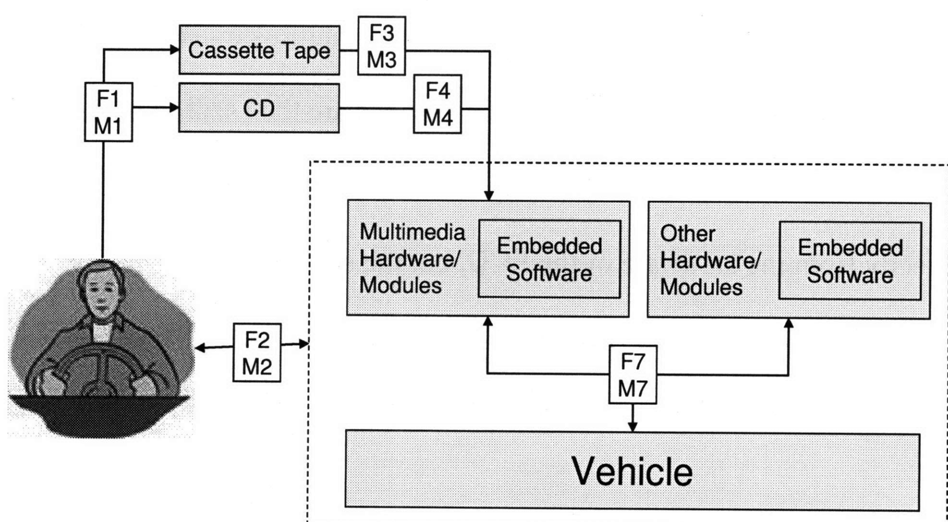


Source: RIAA 1998, RIAA 2006

3.3 Current Multimedia Architectural Analysis

The established architecture for supporting media has involved creating component devices in the vehicle that read and interact with the stored media. The command and control of the media is directed by the automotive component that is outfitted in the vehicle. For instance, the radio head incorporates a CD mechanism for capturing the CD, indexing the media, and allowing the customer to call specific tracks from the CD and play them over the vehicle's speaker system as commanded through the radio head. In this case the architecture is broken down into physical elements that represent the major parts of the system. The following figure illustrates this decomposition.

Figure 3-3: Current Multimedia Architecture



The customer is shown on the left with media formats that are brought into the vehicle environment. The components used to interface with the media are electrical control units (ECU's) with embedded software that is specifically developed for the media player ECU. Typically in the automotive OEM the software is discussed as a whole, without consideration to the components that make up the software modules. Only recently has the separation between software and hardware even become prominent, with the reduced cost of flash technology used to program and reprogram the embedded software. Before this, the module was actually considered a black-box after the launch of the product into the field. Software fixes meant entire modules were replaced, hardware and all (Collela, 2006).

As indicated in the figure above, the software components are released as a single image but they are made up of the multiple components previously described. The image is then loaded to the hardware at the Tier-I module supplier for delivery to the assembly plant. The module assembly is mounted mechanically to the automotive structure and connected to the vehicle electrical system via the vehicle harness. The vehicle wiring harness transports the input and output used by the ECU hardware and software. The signals are then sent to other vehicle modules, displays, motors, switches, etc. It is important to note that interfaces to the consumer can be made directly from the hardware of the ECU, but the software interactions that make functions possible are static over time. That is the features and support is fixed based on the initial release of the code.

When a new media format becomes prevalent in the industry, the automaker develops a new ECU for insertion into the system. The new ECU will consist of new hardware and software stacks to support the new format. In this case the media format takes on the role of a platform that enables innovation at the interface level. Since the platform is stable when compared with the development clockspeed of the vehicle, the vehicle can enhance user experience with playback by continuing to offer unique interface controls like redundant steering wheel switches, advanced display systems for showing media information, and high performance audio systems providing high fidelity playback. The point of the above is that automakers are able to innovate upon the media platform by improving the in-vehicle environment, rather than expending development resources to merely support the media type. The stability of the platform in terms of clockspeed and complexity allows the automaker to create value by continually improving upon the system.

The architectural analysis above provides insight into the factors that determine whether the platform exists. The first question we have from section 2.3.3 is whether a clear interface boundary can be identified. This boundary is clearly the mechanical and information format that is provided in the media type chosen. The next question is whether the platform supports a stream of derivative products. This is affirmed through the adoption of the format in the automobile as well as the continued advances in features and functions like the advanced displays, meta-data information, and better mechanisms for holding and playing. The next question is whether the platform is part of a system that is itself evolving. When the media platform is viewed with the extended stakeholders, the system is clearly described as evolving or changing. The media itself is constantly being updated as attributed by an album's rise and fall on the charts. The consumer electronics industry is changing and innovating around given media formats at a faster rate than automobiles. Finally, is the platform lacking of value outside of the complements that surround it? This is clearly the case with existing media formats. The CD by itself is clearly not valuable without the audio content and the device for playback. Based on these questions, the current media format described in the previous sections can be considered part of a platform business.

3.4 Current Multimedia Platform Stakeholder Roles

In this case the platform leader is the consumer electronics firm which has proliferated a certain format like compact discs in order to make its player dominant in the market place. To carry the previous example, Sony created the CD format and assumed a leadership role in establishing standards that support the proliferation of the platform by spawning complementary products like home entertainment devices, portable player devices, recording components, etc. One of the complements created to enhance the customer's experience with the CD format was the support of the format in the automobile. Once the need was established by the consumer and the volumes reached a level to make incorporation worth the development effort, the automobile manufacturers further solidified the media format platform by adopting the standard.

Table 3-1: Current Multimedia Platform Framework Summary

Need	
Customer Value	Customer value has long been established for in-vehicle entertainment.
Clockspeed Difference	The clockspeed difference in this case actually shows the vehicle as the faster party. This allows the automaker to innovate and keep pace with the media technology
Complexity Difference	As with the clockspeed, the complexity on the media side is much lower than that of the automotive side. There are only 2 prominent media formats at any given point in time.
Architecture	
Collaborative Model	Yes, the automakers and consumer electronics companies choose to adopt a commercially available format.
Modular Interface	Yes, the interface is the media format that is implemented in the multimedia system.
Part Of A Changing System	The media content is changing on a daily basis; therefore the system is evolving over time.
Supports Stream of Derivative Products	This is affirmed through the advent of more advanced playback technologies that are introduced on the consumer electronics and automotive side.
Roles	
Major Stakeholders	The major stakeholders include automakers, consumer electronics industry, and recording studios.
Platform Leader	The platform leader in this case is the firm that successfully promotes a given media type.
Complementors	The complementors are the artists, the automakers, and the consumer electronics industry.

4 Next Automotive Multimedia Need – Mobility Products

This section of the paper establishes the next need in the automotive entertainment. The need involves a new product segment interface that is becoming more prevalent in the consumer electronics space. Again, establishing this need is critical in determining the appropriateness of a given solution.

4.1 Mobility Market Needs

Consumers are using mobile devices to store large amounts data with the ability to generate a rich entertainment or productivity experience while filling time between meetings or events. For this reason, the automobile is a product that is ripe to enhance that experience. Without a means for interacting with these mobile devices, the automobile relegates the consumer to information and entertainment devices of the past, including radio, CD's, and DVD's. Mobile phone use is maintained in its native hardware, missing the opportunity to enhance the user's experience using information and capabilities of the vehicles multimedia systems. In the best cases, users are able to plug one specific type of portable media player and interact with the media according to the predetermined design of the automobile manufacturer. In most cases the user is left only the ability to plug the device in and use the vehicle's speaker system like the headphones of the device itself.

These scenarios described above seem rather limited given the capabilities of their own mobile device, especially given the cost difference between a $300 portable media player and a $30,000 vehicle. Without the capability of enhancing the mobile device's user experience, the automobile experience will continue to be viewed as a completely separate mobility experience, rather than seamlessly integrating into the consumer's preferred mobility experience. For this reason, automobile manufactures are faced with the challenge of creating an interface with the vehicle hardware that takes full advantage of the technology that its consumers choose to carry with them. The goal is to enhance the experience of the user, rather than detract from the experience.

The need for an automotive mobility connection solution is evident in the increasing use of mobility products in the vehicle. Recent reports have indicated that consumers continue to increase the use of devices such as cell phones and media players while driving. In fact a Microsoft paper indicates that 73 percent of cell phone users talk while driving (Microsoft Corporation, 2006), coupled with a statistic that there is an average of 500 million commuter hours (Light, 2002) spent in the United States every week. This is an alarming number of hours given that cell phone sales have been rising consistently over the past several years. Wireless subscriptions have risen from just 340,000 is 1985 to over 194,000,000 in 2005 (Leon and Wang, 2005).

Likewise portable media player penetration has increased dramatically with overall penetration rates jumping from 12% in June 2005 to 28% in June 2006 (Eastwood, 2006). This is also evident in the number of music downloads which have been dramatically increasing over the past several years. The Recording Industry Association of America (RIAA) indicates that single and album downloads have increased 163 and 198 percent respectively from 2004 to 2005 (RIAA, 2005). This increase has led most automakers to aggressively add input jacks to the vehicle offerings allowing the consumer to play the content over the vehicle's speaker system.

The scope of the product segments used in this analysis will include four distinct product segments in the mobility market place as referenced in a paper entitled "The Future of Convergence" by Gary Eastwood. The product segments are summarized below.

Table 4-1: Mobility Market Segments

Product Segment	Description	Market Summary
Mobile Phones	These devices are commonly called feature phones. The devices have some application features, but are not considered "smart" phones based on the lack of true operating system and universal connections.	Feature phone sales are projected to go from about 250M units in 2004 to just under 500M in 2010. (Eastwood, 2006)
Smart Phones	These devices make loading of applications possible by implementing a more open operating system architecture like Palm, Windows, or Blackberry.	Smart phone sales are projected to go from under 25M units in 2004 to over 300M units in 2010. (Eastwood, 2006)
PDA's	These devices carry many of the same features as the smart phones, but are specifically tailored to business and productivity applications	PDA unit sales were at 8.7M in 2004 with projected annual declines in sales of 24% through 2009. (In-Stat, 2005)
Media Players	These devices are specifically designed to playback audio, video, and picture files. They typically do not contain open operating systems for application install.	Device sales increased from 12% penetration to 28% from 2005 to 2006 (Macklin, 2006)

In addition to market pull, safety considerations are leading to legislation limiting the use of the devices while driving. The conditions stipulated in most pieces of legislation involve the use of hands-free systems that allow the driver to keep their attention to the environment. The scope of the legislation is apparent in the number of U.S. states that have banned or are considering banning the use of cell phones while driving. Specifically, 14 states have partial bans in place, 4 states have completely banned them while driving, and 5 states are currently debating legislation (Cellular-News, 2006). These actions, coupled with the dramatic growth in the industry, give rise to a need for a more seamless environment in the vehicle for operating cell phones while driving. Given the rise in the storage capacity of media players, it is possible that these devices could fall into the same driver distraction category as cell phones.

The customer need is summarized as the deeper integration of mobility devices in the vehicle environment, utilizing the information and capability of the vehicle itself. Strides have been made in the following areas for integrating these components, but the execution is either limited in performance, or limited in product scope. For instance, hands-free phone options have been made available through the use of the wireless profile called Bluetooth or through fully integrated telematics systems like General Motor's OnStar. Bluetooth provides the closest implementation of a universal standard, allowing multiple phone manufacturers and service providers to interact with the vehicle through the user's mobile phone. However, the implementation is limited to certain devices and is limited based on the profile that is adopted, which dictates the functions that are supported.

OnStar on the other hand provides the phone and service within the vehicle itself. General Motors has vertically integrated itself into the service limiting the flexibility for the consumer. OnStar customers are unable to change the mobile phone device or select a different service provider based on the latest feature technology that may be available. Similarly, media player connections currently involve two strategies; auxiliary input jack connections and fully integrated command/control systems that target a particular device like the Apple iPod. These implementations are shown in the following figure.

Table 4-2: Automotive Mobility Solution Position

Scope \ Performance	Low	High
High	Auxiliary Input Jack	?
Low		Bluetooth Hands-Free Profile iPod Connection OnStar

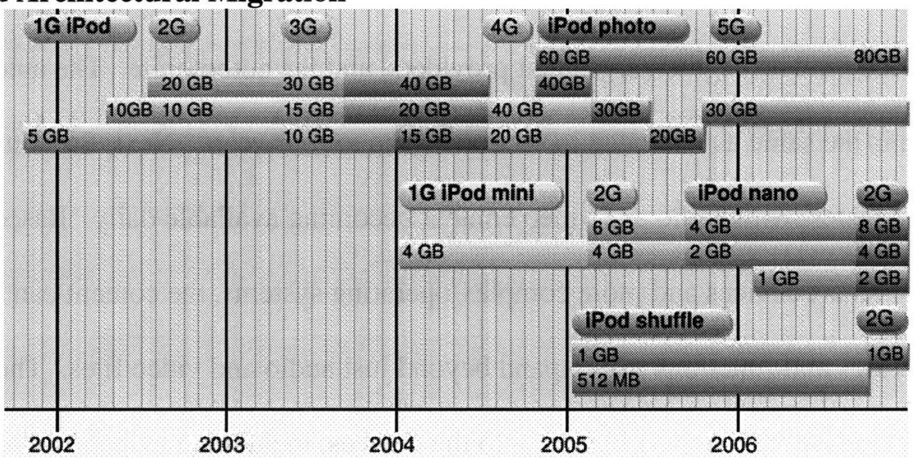
4.2 Mobility Clockspeed Analysis

The next phase of establishing the architectural need for a platform involves identifying the clockspeed differences at the interface between the vehicle and the mobile devices. Section 3 established the baseline for current interfaces excluding some of the options that have been listed in section 4.1. Up to this point the clockspeed of the media interface has been contained through the use of the media platform namely cassette tapes, CD's, etc. Although audio and video content changes within weeks, the format that was used to record the information has remained stable. However, the mobility market has few established common interfaces with which to provide connection to the automobile. As indicated in the previous section, the Bluetooth profile and iPod connections have become the best example of the automakers establishing a common interface for interfacing with these devices.

The clockspeed analysis for this section involves the following categories; the four mobile device product segments, content providers, and the automobile. The automobile product clockspeed is the same as indicated in section 3, two to four years. Next, the content still changes the fastest with audio and video content becoming available daily. Based on the inclusion of smart devices and more complex operating systems, the content can be expanded to include features and functions that expand beyond just audio and video files. These features include applications that can be loaded onto the devices, including navigation systems, productivity software, e-mail, text services, and web connections. For this reason, the content clockspeed is still the fastest moving segment in the domain space being evaluated.

Finally, the mobile device clockspeed is evaluated, starting with the media players. The most dominant figure in this market is the Apple iPod which recently held 9 of the top 10 selling devices in this segment (NPD, 2006). This device has changed generations from 1G to 5G in a period of 4 years (Apple, 2006). In these periods the connection system has shifted the connection system from Firewire to a combination of Firewire and USB. This puts the product clockspeed for this segment at approximately 1 year.

Figure 4-1: iPod Architectural Migration



Source: Apple, 2006

New introductions of mobile phones have been equally as fast. In fact, new mobile phones take the market every year. Java applications in feature phones were supposed to create common applications that can go from phone to phone, but the reality is different. An article in C-Net indicated that writing an application in Java that can be used by all handsets is still not possible (Charny, 2005). Handset makers are unable to wait for the details to be ironed out for a universal application due to the need to get new product out to the market. This indicates that mobile phone clockspeed is on the order of a year or less. The smart phone and PDA market are less susceptible to clockspeed issues based on the stability of operating systems. They rely on the operating system as a platform for connection to personal computers and other complementary products. Charles Fine indicates that product clockspeed for the operating system is between 5 and 10 years.

Table 4-3: Mobility Market Clockspeed Comparison

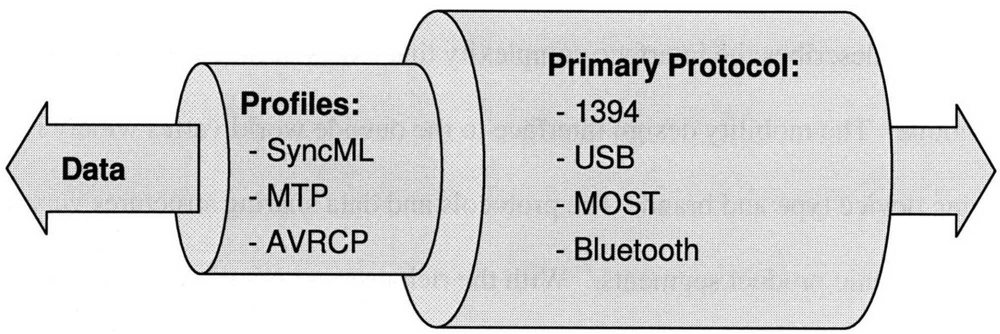
Element	Clockspeed
Media Content	Days
Media Player	<1 Year
PDA's & Handhelds	5-10 Years
Mobile Phones	<1 Year
Smart Phones	5-10 Years
Automobiles	2-4 Years

4.3 Mobility Interface Complexity

This section describes the interface complexity that exists between the mobility market and the automobile. The mobility design interface to the outside world varies widely between and even among device type and brand. The protocols and data sharing structures vary widely in the consumer electronic product segments. With the rich user experience that is created with the devices, comes the interface complexity to deal with audio/video, command/control, data transfer, and connectivity profiles.

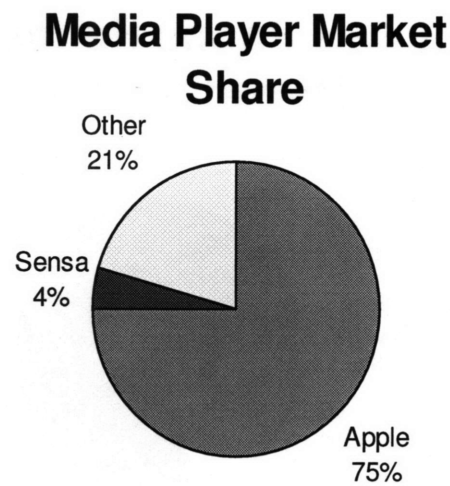
This paper refers to the first level of interface abstraction as the *conduit interface*, whether wired or wireless. For this market the most common connection systems involve USB, iEEE-1394, or Bluetooth. The next level provides the *protocol interface* that is used on the conduit. For media devices this involves profiles like Media Transfer Protocol (MTP), Sync-ML, and iSync. The most common mobile phone interface is the hands-free profile (HFP) within Bluetooth. The smart devices like PDA's and smart phones differentiate the protocol interface at the operating system level, since the operating system typically dictates the protocol interfaces that are supported. Finally, the *data* that is transferred via the protocol and conduit interfaces are indicated. At this level, the complexity is enormous, depending on the function that is being used. At the most basic level audio, video, image, and text can have up to ten commonly used formats in the industry (NIST, 2006). At deeper levels, the data formats can range almost infinitely depending on the application being used. The concept regarding the three layers described above is illustrated in the following figure.

Figure 4-2: Mobile Device Interface Architecture



As indicated above, the portable media devices rely primarily on the device manufacturers' choice of *protocol interface* chosen. Within this market, the primary *conduit interface* is USB based on its proliferation in the personal computer space. Likewise, many of the *protocol interfaces* support various data formats depending on the level of DRM protection added to them. For this reason, the market can be segmented primarily between the Apple iPod interface and the Media Transfer Protocol (MTP) interface developed at Microsoft. The following figure illustrates the relative market share in the media player market based on this breakdown. The data is actually broken down by brand which closely resembles this protocol breakdown.

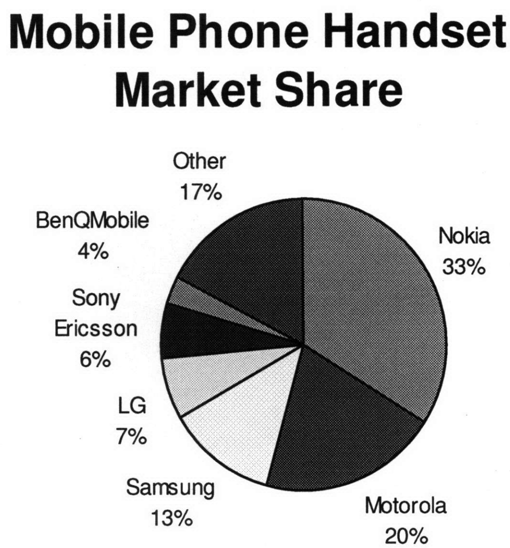
Figure 4-3: Media Player Market Share



Source: NPD, 2006

In the same vein, the mobile phone market interfaces are clearly segregated at the very least by phone manufacturer. The Bluetooth interface is the common conduit for establishing communication, but the applications in this space are largely developed via Java. As previously referenced however, application portability (the ability to transfer from phone to phone) has been largely ineffective (Charny, 2005). For this reason, the appropriate complexity breakdown is done through the mobile phone handset manufacturer. The following figure shows the market share distribution based on the handset manufacturers.

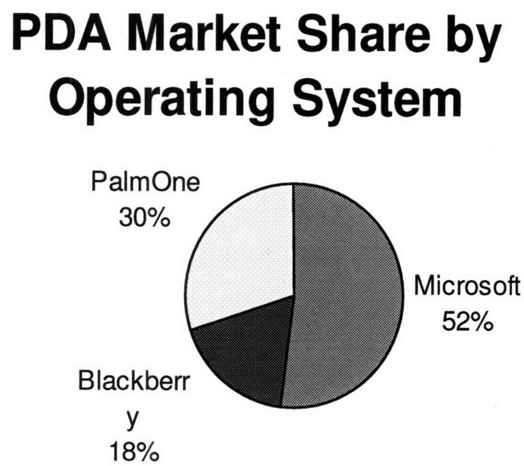
Figure 4-4: Mobile Phone Market Share



Source: Gartner, 2006

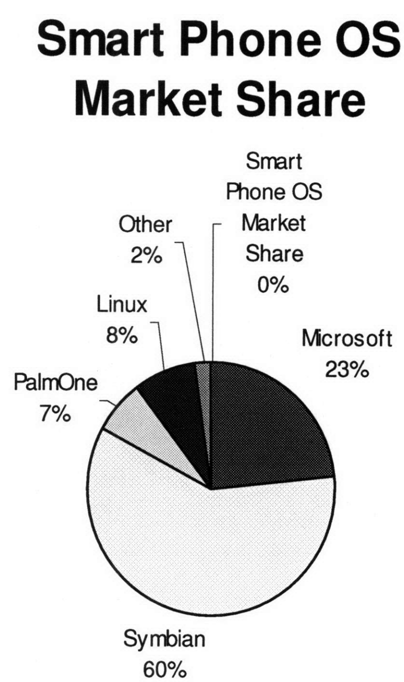
The PDA and smart phone markets are broken down by operating system. For both of these segments the operating system largely determines the connectivity that is supported. In other words, the primary interface is with the operating system itself. Each of these segments carries different breakdowns of operating system market share. The smart phone market is more segmented than that of the PDA market; however Symbian holds a large overall share. The following figure shows the operating system market shares within the given device segments.

Figure 4-5: PDA Market Share



Source: Gartner Dataquest, 2006

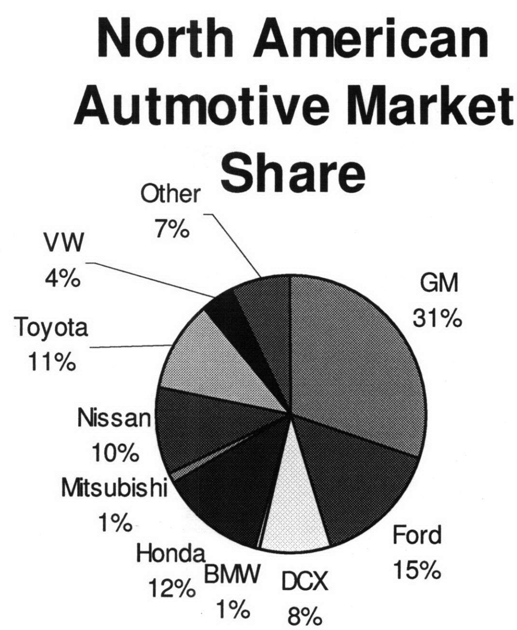
Figure 4-6: Smart Phone OS Market Share



Source: Eastwood, 2006

Finally, the complexity is examined from the other side of the interface. The automotive market has been becoming more segmented and more competitive in the past decade. The following figure represents the market complexity that exists in North America. One might ask why the difference in automakers, shouldn't all cars be generally the same? The answer to that question is no. Different automakers use different communication protocols to access vehicle information. In fact, even if the same protocol is used, the data format is not the same, since the message structure is based on the physical partitioning of the ECU's on the network. For this reason, the post appropriate complexity figure is a breakdown based on the vehicle brand. This is further illustrated in the case presented in Chapter 5.

Figure 4-7: Automotive Market Share



Source: Levy and Ferazani, 2005, pp. 3-4

4.4 Mobility Needs Summary

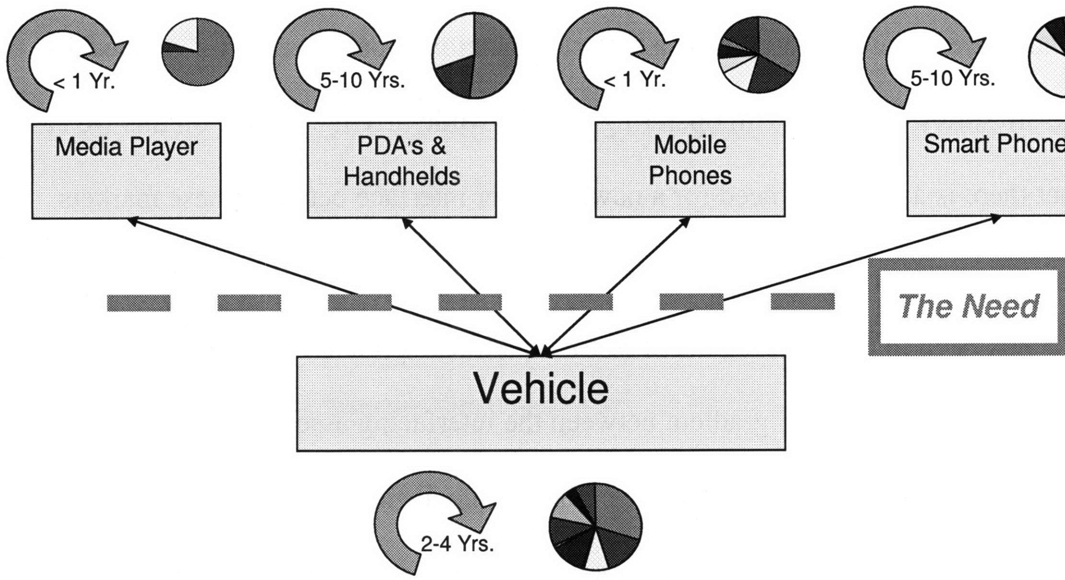
So what do the previous sections represent? First, the need for connecting the mobile device market is evident in the growing numbers of all segments in the mobile device market, coupled with the increased use of these products in automobiles. Given that customers are inclined to use the devices without the benefit of integrating the device and auto, it can be safely assumed that there is value in providing a better connection experience. This is especially true since there are safety concerns with operating devices while driving. Based on this we can assume that there is a customer need for a new or better interface between these markets.

The next step in determining the need for a platform structure involves determining if there is a significant clockspeed gradient between the interfacing assets of the system. In this case, the gradient would be measured between the mobile devices and the vehicle. The previous analysis put the automotive development cycle at 2-4 years for new model introduction. On the other side of the interface we have clockspeeds of one year or less for media players and mobile phones, and 5-10 years for that of the operating system based smart phones and PDA's. This represents a significant clockspeed gradient in the context of this paper.

Finally, we look at the interface complexity at each side of the platform interface. The media player market complexity lies with the protocol interface level and can be broken down into two main segments, MTP and iSync. Mobile phones on the other hand carry complexity levels of seven distinct segments. The PDA and smart phone markets are broken down by operating system and carry complexity levels of three and five respectively.

Putting the need, clockspeed, and complexity together gives the following figure.

Figure 4-8: The Need Summary



4.5 Functional Architecture Based On Needs

Now that the needs have been identified, the foundation for the architectural analysis will be laid based on a functional decomposition summarizing the need. This architectural analysis falls within the needs section because the desired functions do not change with the strategy that is employed. In other words, the tactical solution to the mobility need is based on the translation from function to form. The functional decomposition is born from the need. The primary need of the system is the transfer and manipulation of the data and command information. Data information would consist of items like audio, video, and data files that would currently exist on mobile devices. In addition, data information from the vehicle side might consist of display configurations, vehicle speed, GPS location, etc. Likewise, command information would consist of information such as play, pause, send, end, etc. These are commands that are sent from one element in the system to another for the purpose of providing a desired function or action.

The functions indicated in the customer needs section earlier in chapter 3 clearly involve the integration of data formats from both sides of the market; mobility electronics and the automobile. At the point of integration, the combined data is manipulated and sent back to both sides for use by the end consumer. The following is a breakdown of the basics functions that are considered. It is important to clarify that the functions considered are kept generic, lacking any specific protocol or form-based definitions. This is deliberate, since the decomposition is meant to use universal actions applied to generic elements like data and commands.

4.5.1 Mobility Data/Command Transfer

This function involves the capture of data and commands on the mobility market side. The data and commands that are referenced reside on the target devices in formats that are native to a particular device. The device makes this data and command information available by transferring them to an integration point. This transfer involves some of the following basic functions.

Table 4-4: Mobile Device Transfer Functions

Mobility Data/Command Transfer Functions	
Send	**Receive**
Package	Unpackage
Protect	Unprotect
Transmit	Capture

As indicated in the table, the basic functions on the mobility side of the system are to send and receive data and command information. The primary functions under each involve the collection, protection, and transferring. There are obviously much more intricate activities going on in order to execute these functions, but these are the top-level functions considered in this analysis.

4.5.2 Automotive Data/Command Transfer

The automotive transfer function is identical to that of the mobility electronic market. The base functions are the same, as indicated in the following table.

Table 4-5: Automotive Data Transfer Functions

Automotive Data/Command Transfer Functions	
Send	**Receive**
Package	Unpackage
Protect	Unprotect
Transmit	Capture

4.5.3 Data/Command Integration

The integration of the transferred data/command information from the mobility and automotive markets is a critical aspect of value delivery for the customer. Without the collection of this data/command information, the two markets can remain in their currently separate state. The primary function of the integration site is to collect data/command information from all sides of the system made available through the previously mentioned transfer process. Once the information is collected, it is converted into a common format and made available to the manipulation function. The integration of the data/command information is summarized with the following functions.

Table 4-6: Data Integration Functions

Data/Command Integration Functions
Collect
Translate
Make Available

4.5.4 Data/Command Manipulation

The manipulation of integrated data is where the consumer gets value from the system. It is at this point that the information from the system is used to optimize the user experience. In addition, the vehicle interface capabilities are merged with mobility information to provide the customer with a feature that was not capable with the separate mobility and automotive systems. The primary functions at this point involve the collection of the integrated data/command information, the processing of this information to enable integrated features, the authoring of new information, and finally making this feature information available to the integration point for transfer to the mobility and automotive elements.

Table 4-7: Data Manipulation Functions

Data/Command Manipulation Functions
Process
Author
Make Available

4.5.5 Integration Point Data/Command Transfer

With the creation of the integration point, the need for a transfer function supporting this point is required. The integration point transfer functions remain the same as the automotive and mobility transfer functions.

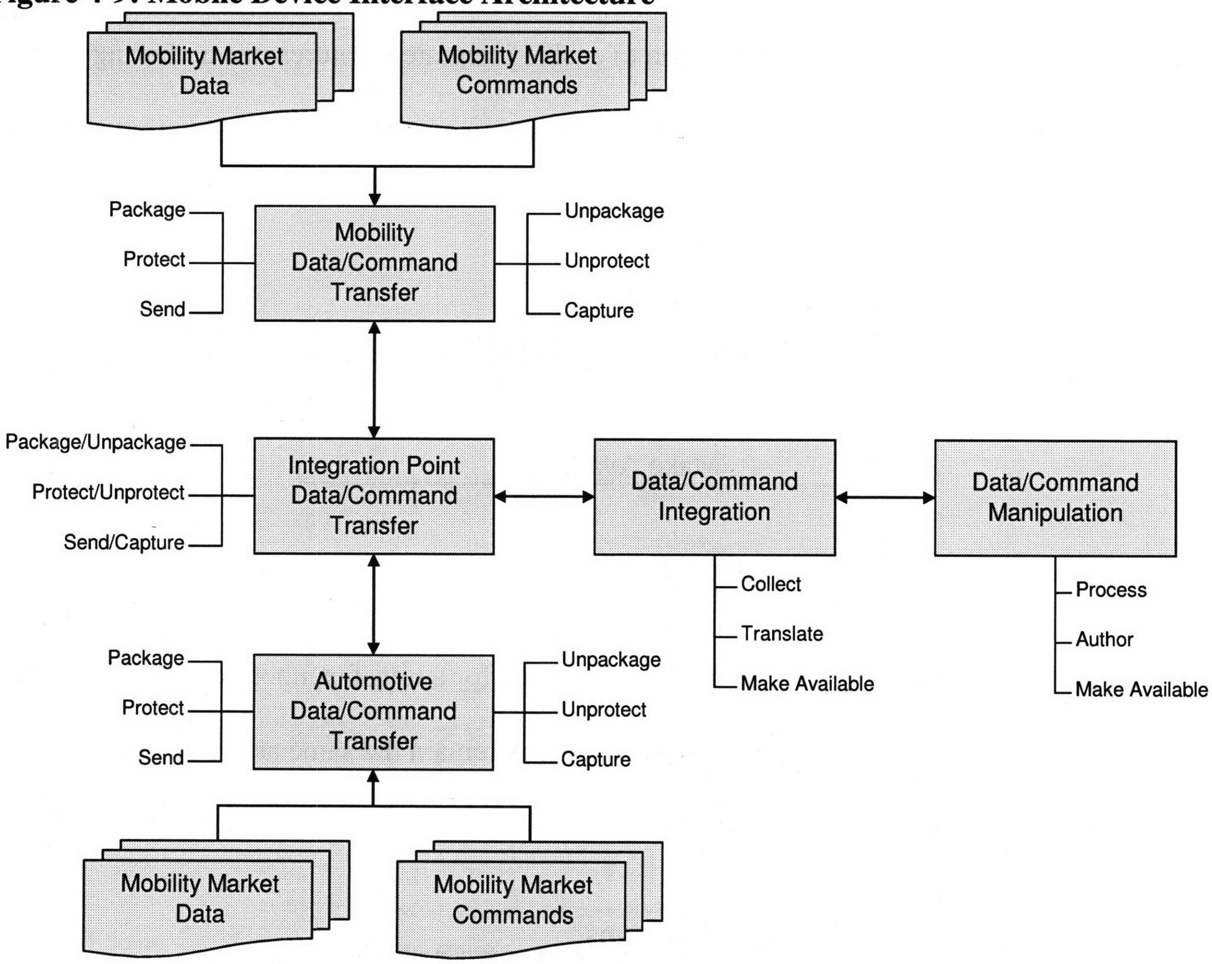
Table 4-8: Integration Point Transfer Functions

Integration Point Data/Command Transfer Functions	
Send	Receive
Package	Unpackage
Protect	Unprotect
Transmit	Capture

4.5.6 Functional Architecture Diagram

The following diagram captures the functional decomposition of the mobility integration need examined in this paper. This decomposition will be used in subsequent architectural analysis, ensuring that focus is maintained on the desired outcome of the system.

Figure 4-9: Mobile Device Interface Architecture



5 Initial Attempt at Automotive Mobility Platforms

This chapter will introduce an attempt to solve the new mobility market interoperability need that was established in Chapter 4. The strategy involves the use of a standards-based approach for the interfaces between the two markets. The following analysis starts where the previous chapters have left off. The needs from the previous chapter carry forward and the functional decomposition that was established in section 3.5 will be converted to a form-based architecture based on the specific strategy employed. Then the rest of the framework established in Chapter 2 will be used to assess the performance of the system.

5.1 Automotive Standards Architectural Overview

One of the first attempts to fill the need identified in Chapter 4 involved the creation of standards for interface design from the consumer electronics and vehicle side of the system. This involved the intense collaboration of many stakeholders in the system with the goal of consensing on a set of specifications that drive the compatibility between systems. This chapter uses the framework identified in the previous sections to determine the appropriateness of this model.

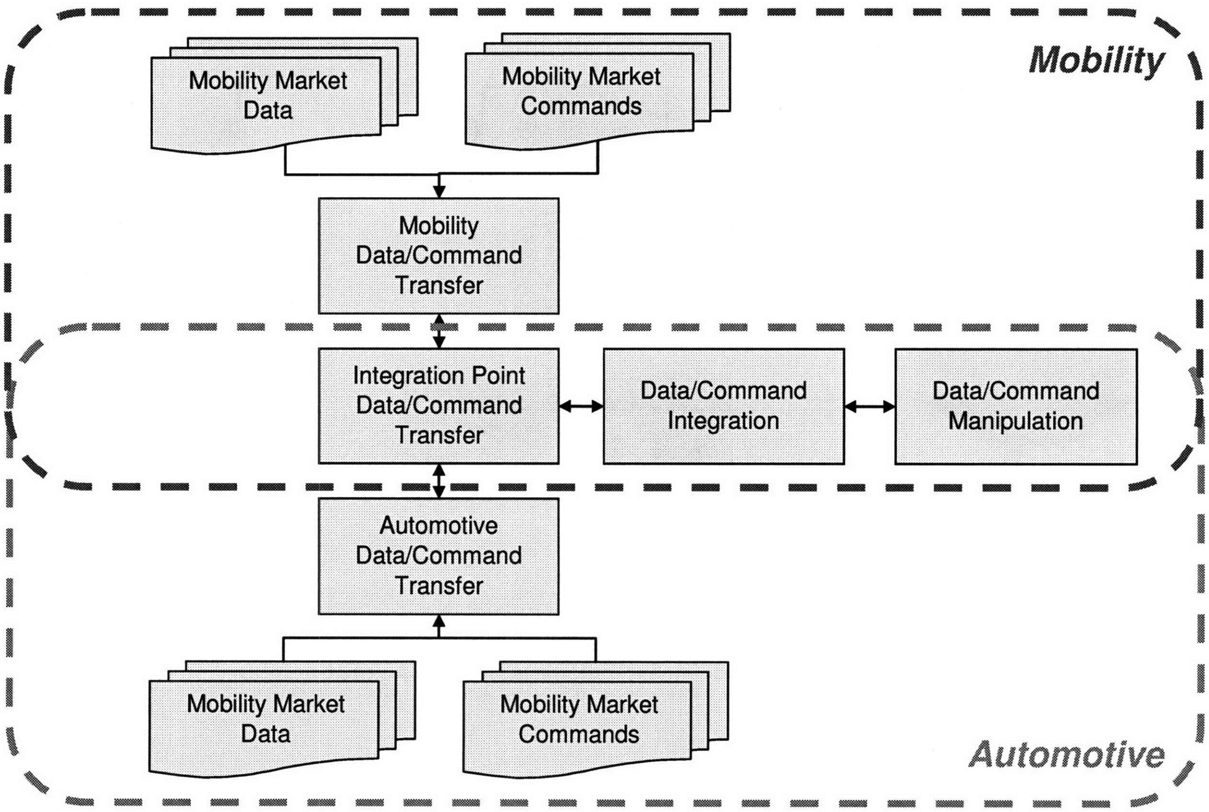
5.1.1 Automotive Standards Strategy

With the platform need established from both consumer needs and technical needs, the architect is left with the tactical dilemma of system design. The automaker is left in a quandary regarding the control of an interface that lies outside of the system boundary that is typically under their direct control. Not only is the interface something that is not under the direct control of the automaker, but the development speed and complexity is faster and larger than that of the automotive industry. For these reasons, the automakers have been slow to introduce actions that create a tighter coupling between the mobile market and the automobile industry.

Recognizing the apparent need, and faced with the complexity and speed issue, the automaker evaluates ways to make inroads into the market. The first choice is to gain volume by collaborating with competitors to create a standard interface that will entice the mobile device manufacturers to settle on a stable interface. This collaboration involves evaluating architectures among the automakers and settling on a common system with specifications that can be used by the mobile device manufacturers, ensuring seamless integration and creating value for the customer. In fact, if the mobile device manufacturers can get involved early in the process, the design can be tailored to their existing products and infrastructure. The architecture that evolves out of this will be an interface platform that shared across the automobile interface, allowing the mobile device manufacturers to uniformly connect and communication with the vehicle.

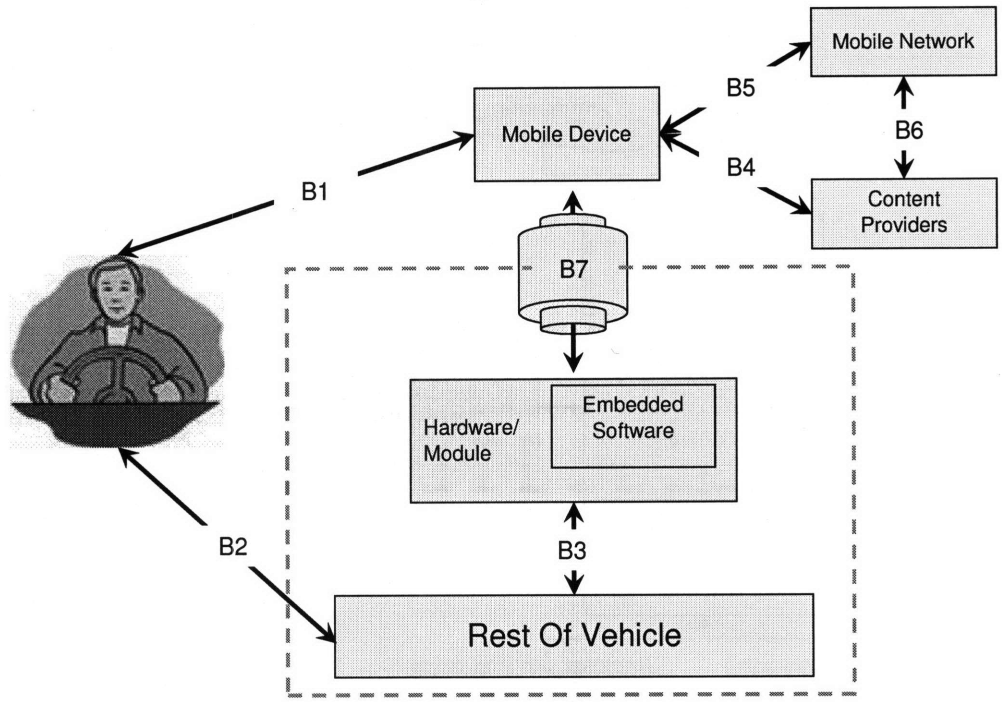
Since the strategy involves the convergence of the interface protocols that exist between the mobility elements and the automotive elements, the integration and manipulation functions that were identified are not specifically handled. The assumption in this strategy is that these functions would be handled at each side of the interface. This is enabled through the use of a common interface in terms of conduit, protocol, and data. The following modification of the functional decomposition diagram illustrates the point. It can be seen that the mobility and automotive markets are sharing the functions in the middle. These functions involve the integration of data and manipulation for the purpose of feature creation.

Figure 5-1: Standards-Based Decomposition



This model is the way the automotive industry progressed throughout the late 1990's and early 2000's. Standards bodies including AMI-C were established to tackle the task of creating commonality at the vehicle interface. This essentially involved evaluating the three core components that were mentioned previously; the conduit interface, the protocol interface, and the data. The following figure shows a revised architectural diagram based on a form decomposition that was established in the previous sections of the paper, showing the specific elements of the system including the mobile device interface. The layered cylinders of interface B7 represent the 3 interface layers identified earlier in the paper; conduit, protocol, and data.

Figure 5-2: Standards-Based Form Decomposition



5.1.2 B1 and B2: The Need Interface

These interfaces reflect the needs of the customer. B1 represents the customer's use of the mobile device, including display, audio, command/control, etc. Likewise, B2 represents the customer's interaction with the vehicle, including many of the same types of interfaces.

5.1.3 B4, B5, and B6: The Mobile Market

These interfaces represent the operation of the mobile devices within their typical setting. The interaction between phones and the service providers are strong, with mobile networks dictating the devices that will be supported on their networks. The mobile carriers have strong influence over the mobile device manufacturers in terms proliferating their devices to the end consumer. Likewise, content providers have significant control over media players and PDA's through the content that they provide to the end consumer through the mobile device itself. For these reasons, the stakeholders should not be ignored during the architectural analysis.

5.1.4 B3: The Vehicle Network

The vehicle network is critical for providing the information that is available in the vehicle environment and accepting information from the external environment. This network involves simple hardwired circuits like switch input/output, as well as complex vehicle communication buses like Controller Area Network (CAN) or Media Oriented Systems Transfer (MOST). The main external interfaces with the vehicle networks have to do with the diagnostic tool connection that is used during service. These networks are generally not made available to the outside market, mainly due to security/safety concerns and the uniqueness of the protocol interface that lies within the conduit interface. Even if automakers use the same network conduit, the likelihood of the message structure and information being common is impossible without significant collaboration. Even the AMI-C architecture developed separates the vehicle interface network from the customer media network via a controlled gateway (Malhotra, 2002).

5.1.5 B7: The Collaborative Platform Interface

This is the center of the collaborative efforts that happed in the last decade. The intent was to communize a set of interfaces for access to the outside consumer markets. These interfaces had to be settled upon in terms of the main conduit(s) that would be supported, the protocol definition or message set and structure, and the data information including standard vehicle Application Programming Interfaces (API's). The strategy involved determining the standard interfaces and making them available to the consumer via a predefined port (USB). The standard message set and API's would allow a compliant device to interact with the vehicle seamlessly.

5.1.6 Architectural Observations

The Architecture viewed the system from a builder-architected system viewpoint. The architects of the system were the automakers themselves. Therefore, the system was architected with the preconceived structure that had previously existed in the automotive industry. In particular the design involved using a consumer interface, with a network structure that was based on automobiles, including IDB/CAN, iEEE-1394, or MOST (Malhotra, 2002). This puts the decision points at one side of the interface; this assumption leads to the architecture being classified as a builder-architected system. The client in this case in the consumer and the mobile device market, however the decisions were made regarding the vehicle design by the vehicle manufacturers with the hopes of adoption by the external clients. This is evident from the makeup of the AMI-C organization which was lead by the automakers as a non-profit corporation (AMI-C, 2006).

Next we look at whether the architecture exhibited a common interface specification or modularity that supported development of derivative products. This attribute is supported by the architecture. The standard specifications developed through the model developed at AMI-C clearly defined a set of requirements that created a form of modularity with the external clients.

Likewise, it can be assumed that innovation could have been supported for derivative products that voluntarily adopted the standards.

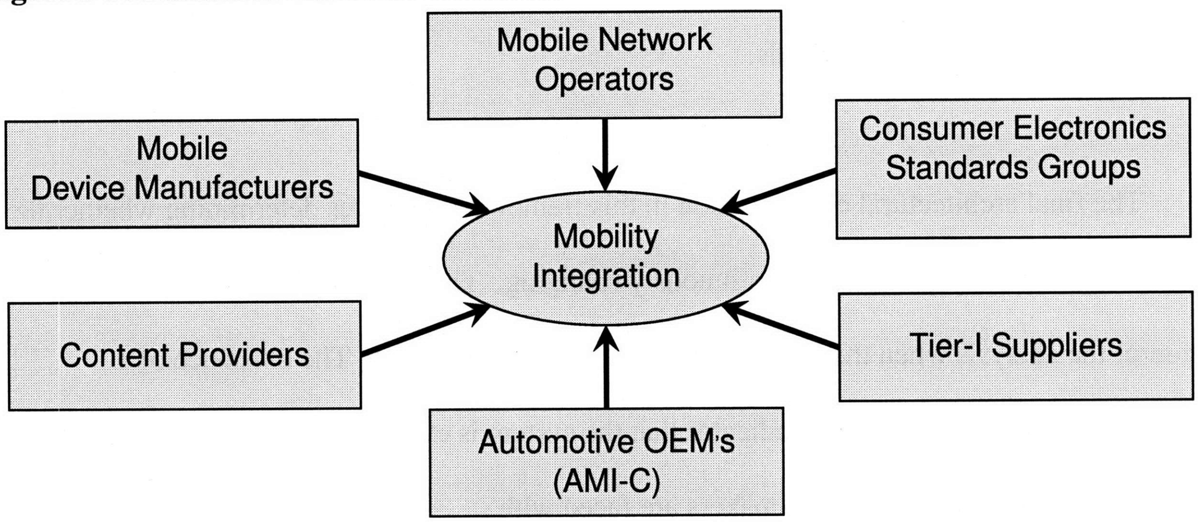
The final architectural consideration in this framework involves determining whether the platform is part of a system that is continuously changing. This is made evident in the needs section of the analysis when the clockspeed analysis was conducted. The existence of a clockspeed gradient in the system indicates that the system is evolving over time. This change is the root of the problem that the automakers are faced with.

5.2 Stakeholder Roles

5.2.1 Stakeholder Identification

Now the stakeholder roles are evaluated in order to identify the leaders and complementors in the system. The intention is to clearly identify the stakeholder roles so that relationship implications can be determined within the system. The following figure shows the stakeholders that were identified in the architectural analysis. For completeness the consumer electronics standards groups and the Tier-I suppliers are listed, even though they are not included in the architectural diagram. The reason for their inclusion is the influence they exert on the system. The consumer electronics standards groups influence the design of the platform to a certain extent, therefore the function they serve is to help the automotive collaboration effort in refining the design (Elliot, 2006). Likewise, supplier Tier-I's influence the design in the same manner.

Figure 5-3: Standards-Based Stakeholders



5.2.2 Standards-Based Leaders

Based on the architectural analysis and the identification of the key stakeholders, we can now determine the roles of the stakeholders in the development of the platform. The stakeholder assuming the leadership role in this case is clearly the automotive OEM collaboration group, based on there drive to solidify specifications for cross brand implementation. In addition to the leadership role, the automotive OEM's will have the role of complementor on the vehicle side of the interface. They will have the ability to innovate on the vehicle side to take advantage of the new connectivity that is incorporated by the other complementors.

The next important attribute of the platform leader is that the platform developed should have no independent value; that is it should have no value without the existence of complementary products. This point is more difficult to clearly identify. However, since the standards were developed around the architecture that already existed in the base vehicle, it is argued that the standard interface clearly *had* value outside of the participation from the external clients. In other words, without the standards developed, the architecture of the vehicle would have to take on some similar approach to get the on-board systems to function as in the baseline case described in section 3. The counterpoint would be that the standards themselves had no value; however, the functions supported in the standards included the pre-existing functions of the vehicle, including interfaces between components like radio control head units, CD changer modules, and the rest of the vehicle network. It is this reason that leads to the determination of independent value.

5.2.3 Standards-Based Complementors

Likewise, the other stakeholders have the role of complementor in this model. The consumer electronics industry, content providers, and network operators have the ability to harness the vehicle connection and create new features in their markets. The automotive tier-I's will have the ability to develop technologies for inclusion in the vehicle that harness both sides of the interface, the vehicle information and the mobile device interfaces.

5.3 Collaborative Standards Summary

Table 5-1: Collaborative Model Summary

Need	
Customer Value	Provides value to the customer through increased automobile connectivity and capability with mobile device targeted markets (mobile phones, smart phones, PDA's, and media players)
Clockspeed Difference	Clockspeed gradient is significant based on the faster developing mobile phones and media players segments.
Complexity Difference	Complexity gradients are significant based on the fragmentation of the four product segments.
Architecture	
Collaborative Model	No, the standards-based system more closely represents a builder-architected system. This is because the system is developed with assumed control by the automakers.
Modular Interface	Yes, the interfaces of the architecture clearly provide a distinct interface boundary.
Part Of A Changing System	Yes, the clockspeed and complexity gradients illustrate a changing/evolving system.
Supports Stream of Derivative Products	Yes, this architecture supports a stream of derivative products if the complementors choose to participate.
Roles	
Major Stakeholders	The major stakeholders include the automakers, media/content providers, carriers, mobile device manufacturers, and tier-I's.
Platform Leader	The platform leadership role in this case is taken on by the automaker. Platform exists in a space with independent value on each side.
Complementors	The complementors include the stakeholders other than the automakers.

5.4 Collaborative Standards Results

So what become of the effort to incorporate the standards that AMI-C introduced? What was the final outcome and was the platform ultimately innovated upon to deliver value to the consumer?

The outcome of the AMI-C strategy was a set of specifications for certain interfaces that lacked incorporation from the automotive OEM and consumer electronics groups. None of the vehicles implemented the architecture in the way in was intended (Collela, 2006). However, it does appear that some OEM's are working towards similar goals. In fact, the non-profit corporation that was formed has since been dissolved with all of the specification intellectual property being transferred to several trade associations that it has been working with. The following is an excerpt from their website. These trade associations are based on the conduits and protocol interfaces that were accepted by AMI-C for standardization at this interface.

> *"With the publication of these specifications, the Board Members of AMI-C proudly declared its mission met and the non-profit corporation has since been dissolved."*
> *(AMI-C, 2006)*

Another reference to the outcome performance of the AMI-C effort is found back on 2001. The article entitled "Slumping Standards – motor vehicle electronics" quotes a marketing manager from Sun Microsystems as saying:

> *"Several advisory bodies, including the Open Gateway Standards Initiative-Vehicle Expert Group and Automotive Multimedia Interface Collaboration (AMI-C), are trying to back a single open automotive standard, but it's been slow going. Lack of unbiased experts, a perponderous consensus process and the sheer scope of in-vehicle technologies continue to block the path"*

(Martin, 2001)

Just before this article was written, AMI-C transitioned from a "cost sharing collaboration" without legal authority to a non-profit corporation. The intention was to gain the legal authority to make decisions faster without gaining 100% consensus from the partners. This coincidentally happened at about the same time as the loss of German automakers in the effort. (Malhotra, SAE 2002)

Similarly, recent interviews with Ford employees that were involved in the effort indicated that not much progress had been made since these articles came out. The specifications were written, but nothing really came of them. They indicated the frustration with the decision making progress and the inability to make all of the parties happy with the specification decisions that were being made. In particular, the choice of specific protocols and interfaces had a significant impact on getting the standards settled and put in place. They indicated that this lack of resolution seemed to be the primary reason for the loss of the German automakers in 2000 (Collela, 2006).

Given the findings of the platform framework that was developed in the preceding sections, it is not surprising that the effort ended in this way. The architectural analysis pointed out a few concern areas with regard to the builder architected model that was used for the system and the independence of the platform leader. The builder architected viewpoint indicates a limited control or scope taken by the system architect. In the case of the AMI-C effort, the specifications were developed for the automotive initiative but never implemented to meet the intent of the organization by any side of the platform interface, consumer electronics or vehicle system. This indicated a lack of scope on the part of the leader in creating incentive to participate and incorporate, even among itself.

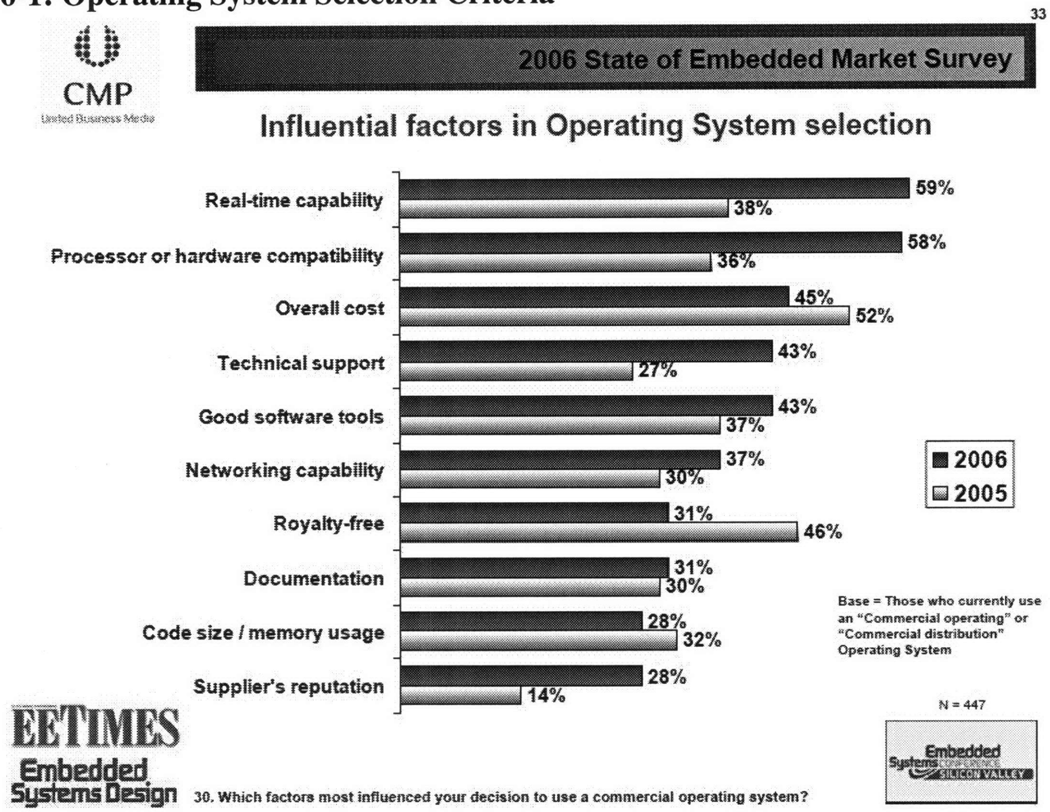
Next we look at the independence of the platform leader, or the existence of independent value that is exhibited by the leader. Specifically, the platform developed had independent value to the automotive OEM's. In reality the outcome of the specification was conceptually like the systems that they already had in place for communication within the multimedia space of the vehicle, the only difference was consensing on a specific implementation. Therefore, the OEM's had little to gain from taking risk in solidifying and implementing the specification according to the group's consensus. In fact, many had a lot to loose in terms of major architectural shifts from relying on a specific network protocol and structure. This is complicated by the cost pressure and market fragmentation that existed in the automotive market. The value of the system relative to the core vehicle development put more focus on arriving at consensus within the leadership stakeholder than that of proliferating the platform by ensuring complementary market development. Without a pre-existing complementary market, the automakers were not incentivized to consense and adopt the standards.

The framework identified in the paper, based on some leading publications in platform development and leadership, have proved useful in pointing out the pitfalls that were seen in the automotive collaboration efforts. Had the framework been used at the onset of the program, the strategic approach to the problem may have been significantly modified. In fact, some mid-cycle adjustments were made to account for some of the performance issues of the system. Specifically, the shift of the enterprise from an informal partnership between firms to a legal non-profit entity, technically separate from the firms that support it. This indicates that they recognized the need to move more towards independence. Chapter 6 describes a new strategy that could have been adopted to solve the problem of consumer electronic or mobility market connectivity to the automobile.

6 Lessons Learned: An Alternative to Current Automotive Mobility Model

The following chapter utilizes the framework to evaluate the latest potential solution to the automotive mobility market platform. This proposed solution involves the incorporation of a commercially available operating system that is sourced from a third-party supplier for the purpose of filling the external platform void. The use of a commercial operating system in the automotive electronics market is not a new concept. However, most of these purchased operating systems are incorporated to aid in the development effort and reduce development time and cost. In fact a recent embedded market survey indicated that primary reasons for selection of an operating system. The results are shown below.

Figure 6-1: Operating System Selection Criteria



Source: CMP Media LLC, 2006

As can be seen from the figure, the primary driving factors for choosing the operating system are have to do with cost and performance. None of the attributes correspond to the external platform benefits, external connectivity, modular interfaces, or support for future application/device development. Basically, these operating systems are not meant to be an external platform according to the taxonomy that was developed in chapter 2.

The operating system proposal that is evaluated in this proposal is meant to fill the *external platform* role. There are a couple of attributes that this paper uses to differentiate commercial operating system from the embedded operating systems that are currently in use. These attributes are summarized below.

- The operating system is commercially available on the market as a complete package to be loaded onto the hardware platform.
- The operating system is considered a platform with which to develop and implement applications for use as assembled or after the first point of sale by the consumer.
- The operating system specifies an interface platform to both the vehicle side and the market side.

6.1 Commercial OS Architectural Analysis

In this section the architectural analysis is performed in the same manner as the previous examples. The model for this system will be the Windows Mobile for Automotive (WMfA) design that has been recently implemented in the Fiat and Alpha Romeo product lines. Fiat calls the feature that incorporates the WMfA platform "Blue & Me." In an article released by Microsoft the company describes the concept of the platform.

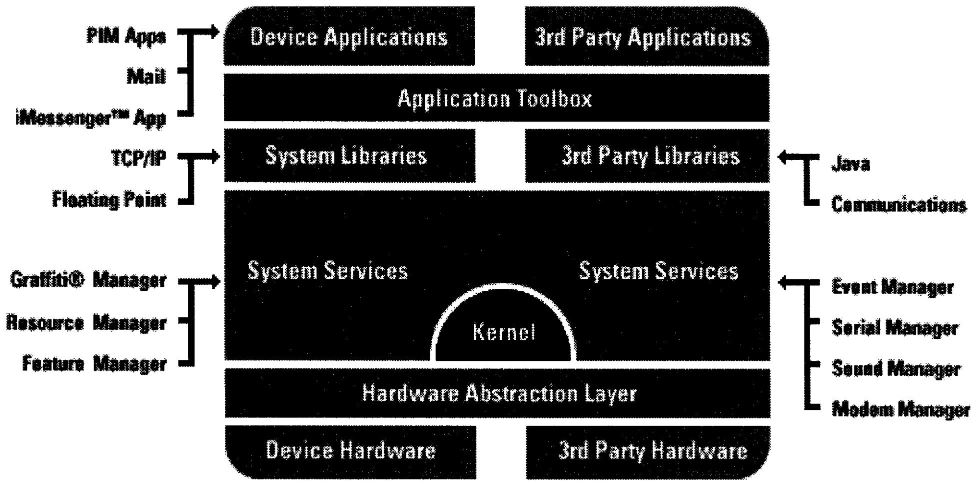
> *Through Microsoft's Windows Mobile for Automotive solution, automakers can use a standardized software stack and hardware reference design to quickly create a consumer electronics gateway that helps drivers and passengers more easily integrate and operate their mobile phones, digital music players and portable navigation devices on the road.*
> *(Microsoft Corporation, 2006b)*

This describes the core concept of the platform that is being evaluated in this paper. The subsequent analysis is meant to be a universal evaluation of the operating system concept, and not meant to be a specific evaluation of a particular OS vendor. However, Microsoft's offering is the first of its kind being introduced on the automotive side of the market. Information is widely available on the concept and the execution of the concept, making this a suitable reference throughout the analysis. To ensure that the analysis is not one-sided, several operating system architectures were reviewed and compared with the WMfA software architecture. As expected, they are very similar in structure, leading to the generalization that implementations provided by other operating system vendors would be similar. This comparison lends validity to the assumption that the coming analysis applicable across multiple operating system vendors.

6.1.1 Operating System Architectures

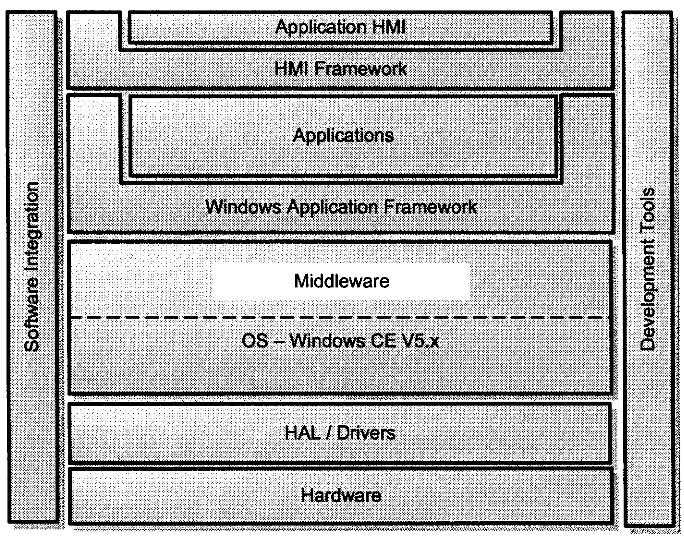
The following figures show some of the mobile operating system architectures that are implemented from Palm, Microsoft, and Symbian. It can be seen that the overall structure remains the same. The lower levels contain the hardware and the base code or kernel that interface to the hardware. The middle portion contains the system level interfaces and core services. Finally, the top levels carry the application space.

Figure 6-2: Palm OS Architecture



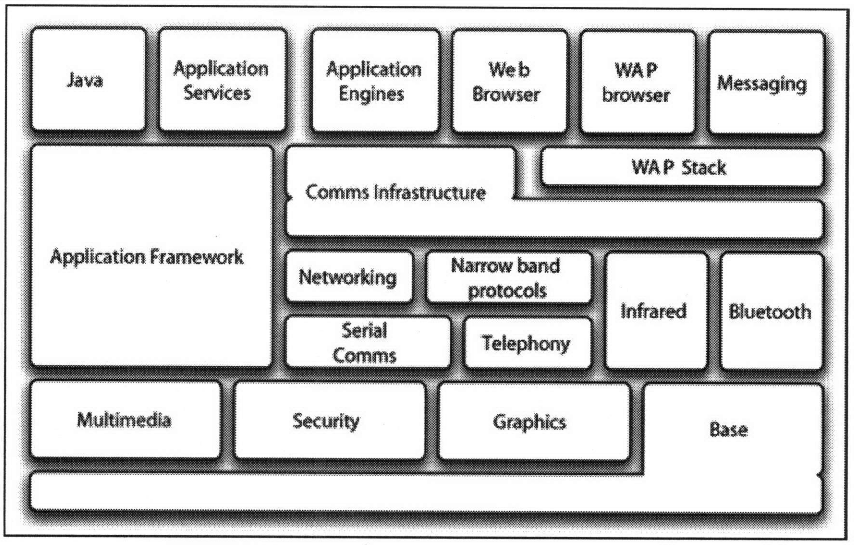
Source: ASP Technology Inc., 2006

Figure 6-3: Windows Mobile for Automotive Architecture



Source: Microsoft Corporation, 2006

Figure 6-4: Symbian OS Architecture

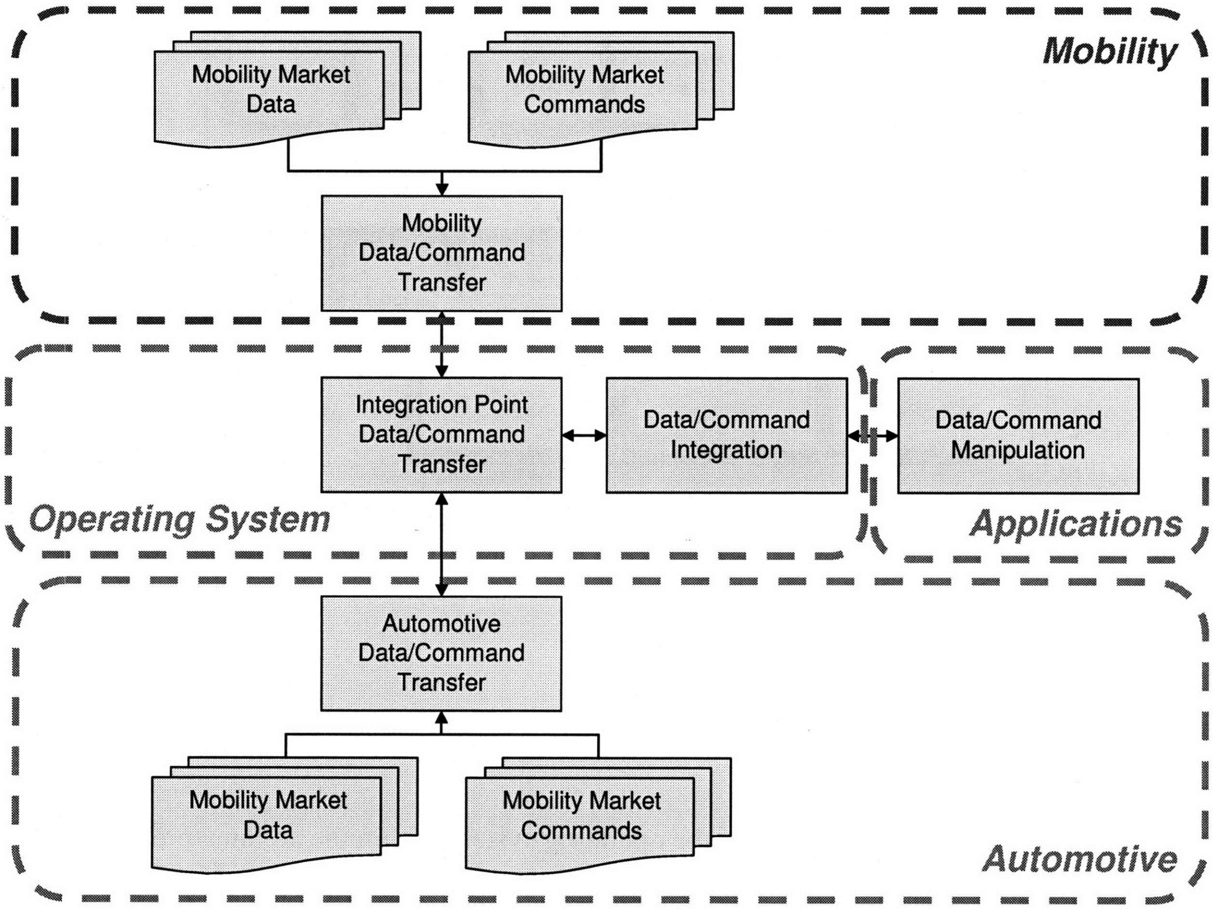


Source: Yuan and Sharp, 2005

6.1.2 Commercial OS Platform Architecture

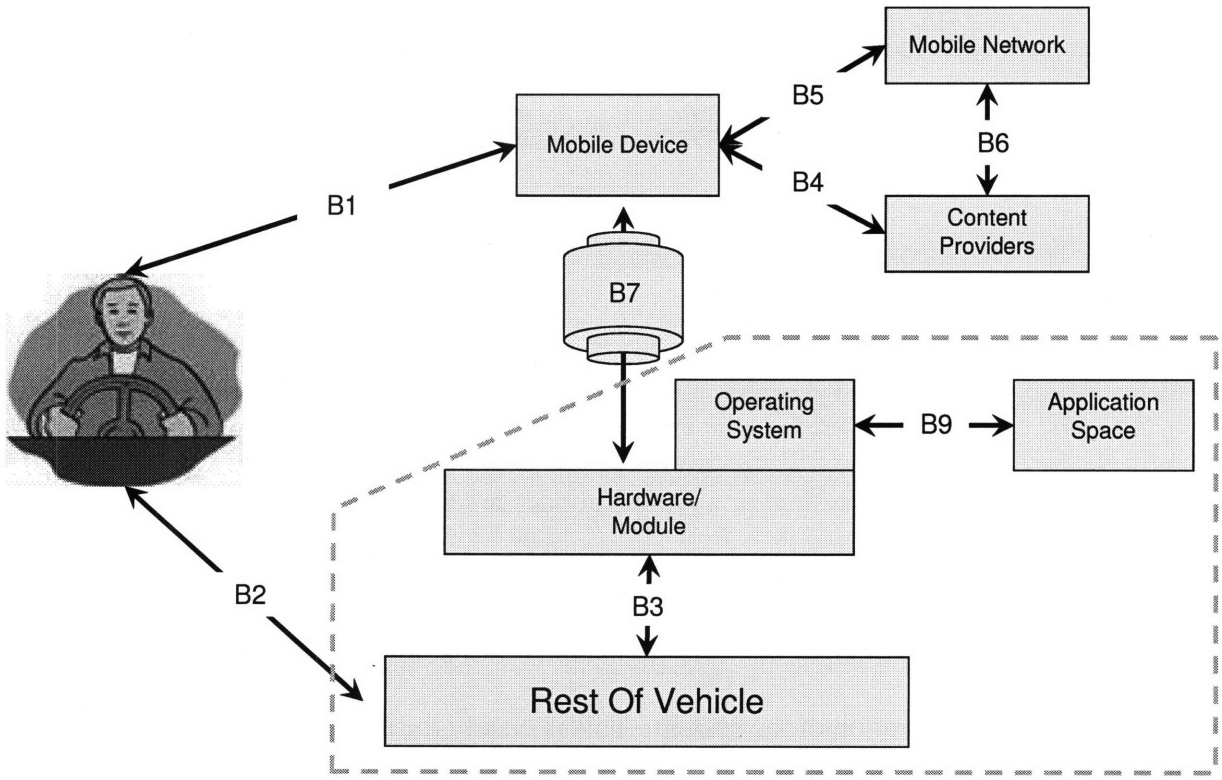
Next, we look at the placement of the operating system within the architecture that was developed in chapter 5. As with the analysis in Chapter 5, this analysis begins with the functional decomposition. This model is used to illustrate the functional partitioning of this particular strategy. The following figure shows the decomposition of the system with respect to the main elements of the system. This will lead into the next portion of the architectural analysis, the form decomposition.

Figure 6-5: Commercial OS Decomposition



In this case the operating system captures the interface that once went directly to the vehicle electronic systems. The difference is that the operating system is put in place to capture the interface and translate them into data and Application Programming Interfaces (API's) for the purpose of application processing. Likewise, the vehicle interfaces are captured and translated into API's for the purpose of application processing. An important aspect of the operating system platform in this context is that it must direct the use of a specific hardware interface or conduit interface that is implemented at the hardware layer of the OS architecture. Operating systems are typically considered pure software, but an important aspect of the operating system is the hardware specifications that must be adhered to in order for the operating system to work properly (Microsoft Corporation, 2006a). The following figure shows the architecture as modified from the previous sections.

Figure 6-6: Commercial OS-Based Functional Decomposition



The key modifications include the separation of the embedded software that used to reside within the Hardware/Module. This was then divided into the Operating System and the Application Space, based on the architectures that were provided in the operating system architectural figures above. The operating system platform in this case is the combination of the Hardware/Module and the Operating System blocks. The new interface (B9) that was added indicates the partition between the operating system and the applications that would be developed outside of the operating system package. These applications are typically called 3rd party applications, representing an open portion of memory dedicated to interaction with the operating system API's.

The evaluation of the architecture involves the same framework comparisons. The attributes that have been identified in section 2.3.3 are used to evaluate the architecture's fit into the desired external business platform need.

6.1.3 Collaborative System Viewpoint

The first evaluation criterion is the viewpoint of the system, or whether the system was viewed as a true collaborative system or a typical builder-architected model as found in the standards collaboration from Chapter 5. To reiterate, a collaborative model is one in which there is no central control over participation. The elements or assets of the system are willing participants in the incorporation of the system. This is clearly the case with the architecture described above. The system by definition involves the use of a 3rd party commercially available operating system. The only point of control that the automakers have is to participate in the design of the system by implementing the operating system in its architecture, or choose not to participate. Participation in the system involves designing the vehicle interface to the interface specification of the operating system as designed.

6.1.4 Modular Interface and Derivative Product Support

The next point of evaluation involves the creation of a modular interface. This design addresses the modularity attribute by creating fixed interfaces facing three of the major design elements; the vehicle, mobility market, and application space. The interfaces at the vehicle side are determined by the hardware reference design that is incorporated with the operating system. In the case of WMfA the interface is specified as an industry standard Controller Area Network (CAN) network, general purpose hardwired I/O, A/D, audio interface, phone module, and resistor ladder support (Microsoft Corporation, 2006a). The decision by the operating system vendor to dictate the interface represents the modularity that is created across the industry. Again the automaker is a willing participant in its incorporation. For example, although the conduit interface is specified in the network protocol, the operating system is able to handle the specific implementation at the protocol level. The WMfA paper indicates the support of a "vehicle-specific CAN message map" in order to accommodate the different message sets that may exist between manufacturers (Microsoft Corporation, 2006a). The data interface, or information that is found within the messages, is then designed to interact with the operating system API's that are resident in the software.

The next interface evaluated for modularity is the interface between the operating system and the external environment, in this case the environment comprising of the mobility devices. This interface is controlled in the same manner as the vehicle interface. Again, in the case of WMfA, the interfaces are defined as the Bluetooth and USB. These interfaces are again dictated by the operating system supplier and made universal across the industry. The operating system incorporates some base services like Hands Free Profile (HFP) for communicating on Bluetooth. The information supported in this profile is then made available to the applications via API's.

This leads to the next interface, the communication between the operating system and the application space. In this case, the interface is handled through the API's that are specified in the operating system. These API's determine the functionality that can be translated from the vehicle interface and the external interface.

The evaluation above clearly provides evidence of a modular boundary. The commercial availability of the operating system with common interface specifications creates a consistent boundary for the interacting elements to incorporate. The willing participants must evaluate the interface and make specific decisions to create custom designs for ensure compatibility, or incorporate specific profiles that are supported by the operating system. In order for the system to be modular at the interfacing elements, the design of the interfaces must be made available to the interfacing elements of the system. The intention of the standards-based systems was to provide an open specification that could be adopted, creating derivative products from the platform. The intentions of a commercial operating system need to be specifically evaluated for the delivery or presentation method including open standards, licensed designs, etc.

6.1.5 Continuously Changing System

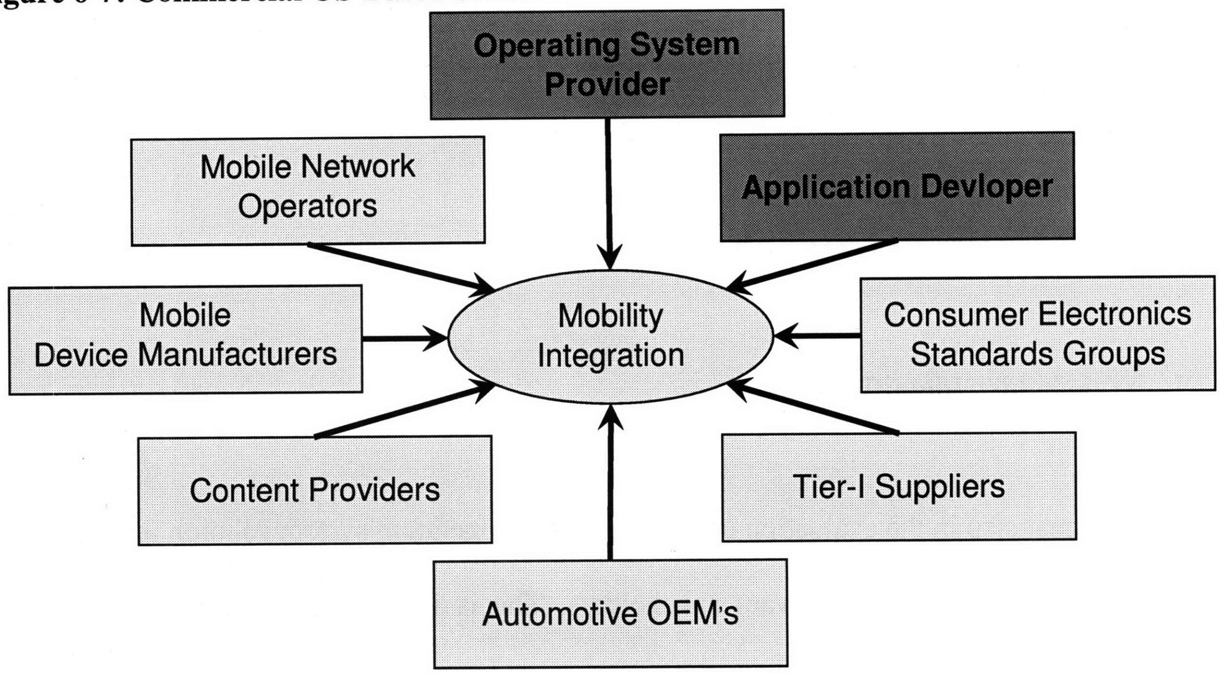
The next critical evaluation of the solution involves the determination of a continuously changing system. This condition is carry-over from the previous analysis of the standards based solution. Section 5.1.6 makes the assertion that clockspeed boundary gradients at the targeted interface indicate that the system is changing over time. This condition does not change based on the chosen solution, at least in this particular implementation.

6.2 Commercial OS Stakeholder Roles

6.2.1 Stakeholder Identification

The next step in the evaluation of the commercial operating system solution involves identifying and classifying the relevant stakeholders. This is done in the similar fashion as the standards-based solution analysis. The combination of the functional decomposition and the form decomposition are evaluated and key contributors are identified. In the case of the commercial operating system approach, the identification of the operating system form indicates the creation of the operating system firm as an additional stakeholder in the system. Likewise, as in the previous section, the application developers become another important stakeholder in the system. The modified stakeholder diagram is provided in the following figure.

Figure 6-7: Commercial OS-Based Stakeholders



6.2.2 Operating System Leadership

The leader in the commercial operating system solution is clearly the firm supplying the operating system for incorporation into the vehicle system. In the case of the WMfA example, Microsoft would assume the platform leadership role in the system. If another operating system were chosen for implementation, that firm would assume the leadership role in achieving compatibility between the elements of the system, and more importantly fostering innovation at the interfaces for increasing consumer value.

A critical aspect of platform leadership in a collaborative system model is the lack of independent value, without the participation of the interacting elements. This evaluation seems straight forward for the commercial operating system, but in reality proving the lack of independence takes some thought. The function of the operating system is to serve as the interaction between the main assets of the system, including the vehicle system interfaces and the mobility market interfaces. This is the same function that was accomplished using the standards based approach, and this implementation was considered to have independent value. However, in the case of the standards-based approach, the lack of independence was based on the function being absorbed into the normal architecture of the vehicle. In other words, another element in the form-based architecture was not established for the standards based approach, rather the base design changed based on the revised specification.

In contrast to the standards-based design the commercial operating system solution involves the creation of two additional elements in the form architecture; the operating system and the application space. These elements are separate physical forms in the design, and the operating system is a different commercial entity by design. The application space also has the ability be sourced outside of the typical stakeholder elements depending on the arrangement that the automakers choose to engage. These elements represent significant modifications to the typical automotive architecture.

Now that the operating system has been established as a stand-alone entity in the architecture, the independence of that entity needs to be determined within the context of the system. This part of the analysis is fairly straight forward. For this we need to look at the operating system element and determine if the element has functional value as a stand-alone entity. In the case of all operating systems, these elements exist to manage interfaces between other elements, therefore the operating system is considered to have no independent value.

6.2.3 Operating System Complementors

Next, the complementor space is identified. In this space a new entrant has been identified, that of the application developer. As indicated previously in the paper, the existence of this stakeholder as an independent activity is largely dependent on the vehicle system stakeholder's design of the boundary. Unlike the operating system element which was purchased as a separate component in the system, the application space has the ability to be a closed space depending on the strategy of the incorporating vehicle system. If the automaker decides close the development and deployment of the application space, the automaker assumes the complementor role of this particular space. However, if the automaker chooses to open this space to outside firms, the space becomes a distinct space to innovate upon from the outside.

One consideration in the above analysis is the recent blur between the operating system and the application space in the personal computers. This case was brought out in Platform Leadership regarding Microsoft's competition in the web browser market. One of the complaints from Netscape regarding Microsoft's delivery of Explorer was the fact that is was included with the base operating system package, of which Microsoft had a significant share of the personal computer market (Gawer and Cusumano, 2002). The distinction between the operating system and the browser function became critical in determining fair market practices within this space. Likewise, it is likely that applications will be developed and included in the operating system, regardless of which operating system firm is used.

The other stakeholders included in the system have the same role for creating innovation as identified in the standards based system. However, the implementation of the complementors will consist of designing the interfaces to interact with the operating system interfaces, rather that to the specifications that were established by the standards body.

6.3 Commercial OS Summary

6.3.1 The Architecture

The commercial operating system solution described in this chapter meets all of the attributes in the framework for a valid external platform system. The system that is being evaluated is clearly evolving and changing over time. This is the basis for establishing the platform need. Next, it is has been shown that the model used in the definition of the system is a true collaborative model. Participants in the system are complementors that are willing participants in the overall system function. The stakeholders identified are not under the central or direct control of the architect, as is the case of a builder-architected system.

Next, the operating system, by definition, provides the modular interfaces necessary for complementary innovation. The purpose of the operating system in any design space is to provide a common framework for the integration of hardware and software interfaces by translating the information into common terms for use by the applications. The applications use these common terms to manipulate or create additional functions enabled by the combination of interfacing components. This being said, the operating system solution described above meets the needs of creating a modular set of interfaces in the space needed.

6.3.2 Platform Leadership

The leader in this solution space is the operating system vendor. The operating system clearly exists for the purpose of creating a modular interface between the mobility market and the vehicle system. The lack of independence is identified in the previous section. This lack of independent value from the operating system creates the incentive for the leader to drive complementary innovation, thus pushing the platform proliferation and value creation for the end consumer. This is a very important attribute of the collaborative system platform leader.

6.3.3 The Complementors

Complementors were identified in this analysis, which include the same stakeholders as in the standards based approach, with the addition of one; the application developers. This new stakeholder provides some interesting implications to the automaker looking to adopt this platform strategy. Specifically, the automakers should be concerned about the intent of the other stakeholders in competing within this newly developed stakeholder role. Since the application space actually lies within the automotive architecture (from a form perspective), the automaker has the ability to open or close this space for complementary development. Each strategy has significant implications on the progression of the platform and the benefits achieved from platform adoption.

Table 6-1: Commercial OS Summary

Need	
Customer Value	Provides value to the customer through increased automobile connectivity and capability with mobile device targeted markets (mobile phones, smart phones, PDA's, and media players)
Clockspeed Difference	Clockspeed gradient is significant based on the faster developing mobile phones and media players segments.
Complexity Difference	Complexity gradients are significant based on the fragmentation of the four product segments.
Architecture	
Collaborative Model	No, the standards-based system more closely represents a builder-architected system. This is because the system is developed with assumed control by the automakers.
Modular Interface	Yes, the interfaces of the architecture clearly provide a distinct interface boundary.
Part Of A Changing System	Yes, the clockspeed and complexity gradients illustrate a changing/evolving system.
Supports Stream of Derivative Products	Yes, this architecture supports a stream of derivative products if the complementors choose to participate.
Roles	
Major Stakeholders	The major stakeholders include the automakers, media/content providers, carriers, mobile device manufacturers, and tier-I's. In addition, the operating system vendor and applications provider is added.
Platform Leader	The platform leadership role in this case is taken on by the operating system vendor. Platform lacks independent value.
Complementors	The complementors include all stakeholders in the model since it is likely that they operating system vendor (leader) will participate in a portion of the applications space (complement).

7 Conclusion

The objective of this paper is set around two primary goals. The first was to provide a framework for future analysis in the area of mobile consumer electronic and automotive convergence. The second goal involves analyzing the leading solutions to this need based on the framework developed. The overall intention is to better understand this problem space and provide direction to those stakeholders involved in each solution analyzed. As well, future analysis should be continued to further develop optimal strategies for value delivery.

7.1 Framework Summary

The following provides a summary of the framework that was developed in chapter 2. This framework is divided into three main sections; the need, the architecture, and the stakeholder roles.

7.1.1 Step 1 – Establish the Platform Need

The first part of the framework used for the analysis involved determining the major drivers of external platform creation. This requires the clear identification of the need being addressed. After investigating several of the leading publications in platform product strategies, two key attributes were used to determine the appropriateness of a platform strategy. These attributes are listed below.

1.) Clockspeed gradients – The condition where interfacing external products evolve at different rates.

2.) Complexity gradients – The condition where interfacing external products involve different interface structures.

The first of these is the clockspeed gradient that exists between the product segments being analyzed. This was drawn from research that was centered on Dr. Charles Fine's book on the subject of industry clockspeeds (Fine, 1998). In this book it is determined that different industries have inherent clockspeeds or cycle time for product and process developments. These clockspeeds are critical in categorizing how fast the firm or industries operate. Further research by Nathan Everett coins the term "clockspeed collision boundaries" for product segments that interact, but have different clockspeeds (Everett, 2003). For this reason, clockspeed gradients are considered a primary driver for the pursuit of a platform strategy.

The second attribute that indicates the need for a platform strategy is complexity. This follows the same logic as the clockspeed gradient described above. The main idea is difficulty in coordinating product releases between two industries or firms due to inherent differences in the operations. In the case of clockspeed it was the difference in the cycle time to release the products. In the case of complexity, it is the number of interfacing product segments that can cause release coordination issues.

Either of these issues creates coordination issues for releasing products that interact with one another, but when both complexity and clockspeed gradients exist in certain combinations, the creation of a platform interface becomes critical to maintain interaction. In other words, take for example Firm A which is interfacing with Firms B, C, D and E. With complexity alone (clockspeed is the same between all 5 firms) the likelihood of release coordination without significant collaboration is remote. The only way that independent release coordination could happen is the introduction of a clockspeed gradient in which Firm A develops significantly faster than B, C, D, and E. If the situation is reversed and Firm A actually develops at a slower pace than that of the other firms, then the interface must be insulated through the use of a stable design.

7.1.2 Step 2 – Critically Evaluate the Architectural Alignment

Once the platform need is established through the existence of clockspeed and complexity gradients, the platform architectures need to be evaluated for proper fit. This fit is determined by critically evaluating proposed architectures to determine their appropriateness with respect to external platform creation. For this, several architectural models were evaluated and some of the key attributes for successful platform architecture were compiled. These attributes are the following:

3.) Collaborative systems model – The primary indicator for this condition is the lack of central control over stakeholders

4.) Modular interface layer – This condition involves insulating the external products through the use of a stable interface.

5.) Part of a system that is continuously changing – The system that is being evaluated should be dynamic and evolving over time.

6.) Supports derivative products – The developed platform should enable the stakeholders to develop new products at the boundary.

The architectures are evaluated through the lens of these attributes to rate the effectiveness of the architectural proposal. The intent is to satisfy all of these attributes with a given proposal. This evaluation can be used by key stakeholders to critically compare proposals or existing architectures.

7.1.3 Step 3 – Identify the Stakeholder Roles

The final phase of the evaluation involves the tactical implications of a given solution or architecture. This portion of the analysis was based on Gawer and Cusumano's Platform Leadership book (Gawer and Cusumano, 2002). In this book, key stakeholders are identified and roles established that include complementors and leaders. The key role of the external platform is the leader. The platform leader has the role of establishing the modular interface design, and more importantly fostering innovation at the interfaces. This platform should stand as a dependent entity within the system. That is, it should lack independent value, creating the incentive for the platform leader to foster complementary creation. This innovation spurs complementary products that further promote the platform. Without an understanding of the stakeholders and their roles relative to the platform, tactical execution of the platform strategy becomes difficult. This is critical regardless of the viewpoint, whether from the view of a complementor or from the viewpoint of the leader.

7.2 Solution Summary

The following section summarizes the application of the platform framework to two of the leading solutions to the automotive mobility need. The first of these solutions involves an automotive led effort to develop and implement a standard consumer electronic interface. The second involves a more recent proposal to voluntarily incorporate a commercial operating system in the automotive electrical architecture.

7.2.1 Established Mobility Need

The analysis of the paper is centered on the interface issue that exists between the rapidly changing mobility market and the automotive infotainment field. The mobility market that is being considered in this paper is broken down into four categories; mobile phones, smart phones, PDA's, and media players. These devices are growing in popularity, making interaction in the vehicle environment more critical. Given this consumer need the question remains, why do the existing product offerings in this area from the leading automakers lag in incorporation? The answer lies in the interface design and implementation strategy.

When comparing the mobility and automotive industries across the interface, it can be seen that there is a significant disconnect between the development cycle at any one automaker, and that of the mobile device market. This is summarized by the table below.

Table 7-1: Clockspeed Comparison Summary

Segment	Clockspeed	Segment	Clockspeed
Automaker	2-4 Years	PDA	5-10 Years
		Media Player	<1 Year
		Smart Phones	5-10 Years
		Mobile Phones	<1 Year

The next portion of the framework analysis involves determining whether a complexity gradient exists between the industry segments. The analysis shows that there is a significant amount of product complexity on both sides of the platform interface. This is summarized in the following table.

Table 7-2: Complexity Comparison Summary

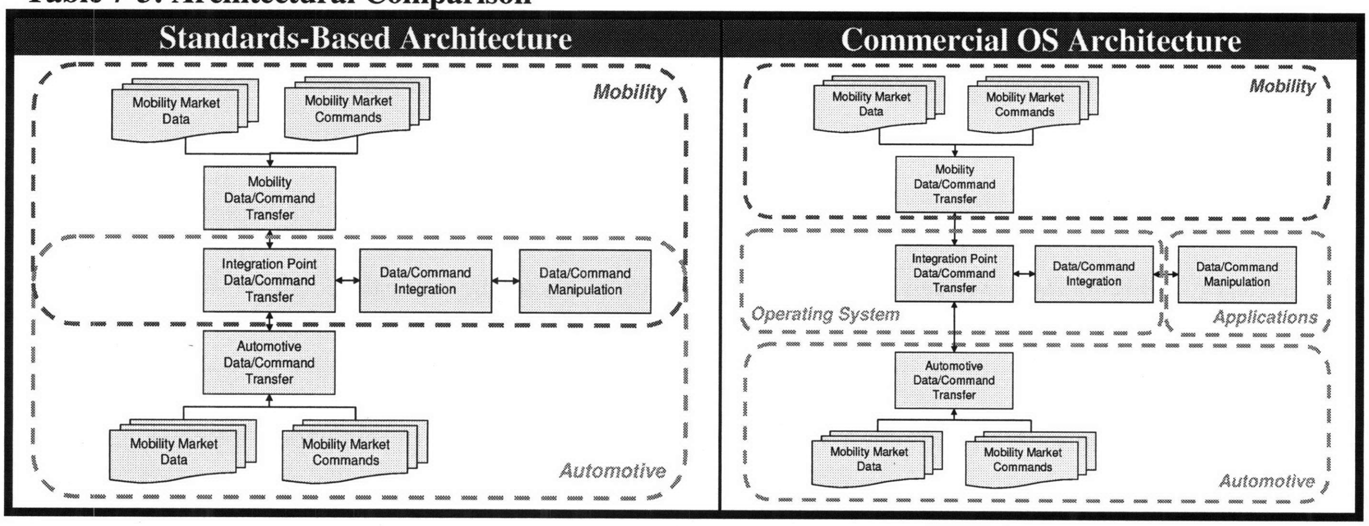
Segment	Complexity	Segment	Complexity
Automaker	9 Major Segments	PDA	3 Major Segments
		Media Player	3 Major Segments
		Smart Phones	5 Major Segments
		Mobile Phones	7 Major Segments

7.2.2 The Architectural Options

Step 2 of the analysis involves the evaluation of two key solutions that are being evaluated. The first solution is the collaborative systems model that was best implemented by AMI-C. This model involved establishing the automakers as the central decision body for the establishment of a common interface specification. However, there are some limitations of this strategy that were identified when using the framework developed in this paper. Specifically, the implementation assumed an architectural viewpoint that best matches Maier and Rechtin's builder architected model, rather than the preferred collaborative systems model. This means that the AMI-C solution assumed a central control could be maintained among independent market segments.

Conversely, the alternative solution evaluated in chapter 6 of this paper involves the incorporation of a commercial operating system in the automotive electronics modules. This operating system, along with the associated hardware platform design, would establish the interfaces that exist between the automakers and the mobile consumer electronics markets. This solution specifically addresses the shortcomings of the standards-based solution that was proposed by AMI-C. In particular, the central control assumption that was key to the standards-based solution is replaced by a third stakeholder, the operating system vendor. This stakeholder has no direct control over implementation within the system, it is a voluntary participation model on both sides of the interface. This is illustrated in the following architectural comparison in which a separate interface component comprising the operating system and applications is placed between the interfacing product segments.

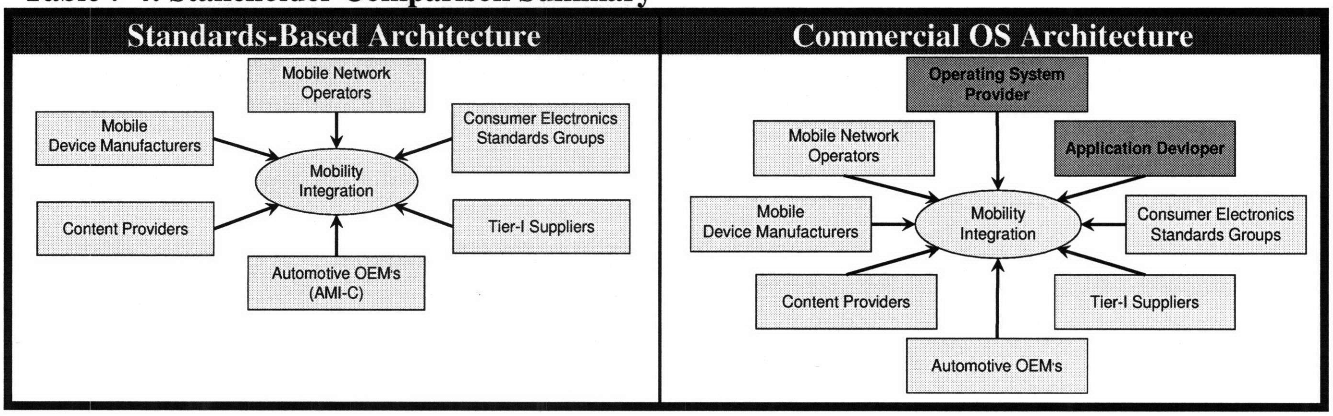
Table 7-3: Architectural Comparison



7.2.3 The Stakeholder Roles

The stakeholders identified in each of the two scenarios involve the automakers, mobile device manufacturers, mobile network operators, content providers, Tier-I suppliers, and various standards groups. In the commercial operating system solution, there are two additional stakeholders that are added, the operating system provider and the applications developer. The stakeholder summaries for each of the two solution proposals are shown side-by-side in the following table.

Table 7-4: Stakeholder Comparison Summary



The important aspect of this step in the analysis is the identification of the leader. In the case of the standards-based approach, the automakers assume the leadership role in designing and proliferating the platform design. This is done through the specification and implementation of the interface specification. This key assumption is what drives to the architectural viewpoint described in section 7.2.2 where the automaker assumes central control.

The commercial operating system leadership role is assumed by the operating system vendor, which is essentially a third-party that is put in between the automakers and the mobile electronic markets. As such, the architecture resembles the desired collaborative systems model. The leader in this case is expected to proliferate the platform by enticing complementary development by the interfacing stakeholders. In other words, the operating system vendor should have plans in place to allow for rapid adoption and proliferation of the platform.

7.2.4 Summary and Recommendations

As indicated above, the lack of movement from the automakers in mobile device integration shows the difficulty in successfully implementing the standards-based model that was developed by AMI-C. At first glance, the solution seems to address the concerns seen by the automakers, especially when the proposal is evaluated based on a traditional automotive product development activity. The major issue is the justification of making the system changes required in the hopes that the consumer electronics industry with adopt the standard. In other words, the automakers are left with the leadership role of fostering innovation by the non-automotive stakeholders. This is difficult considering the independent value that exists in the mobile device market. Why would the mobile device manufacturers choose to incorporate a specification in the hopes that a significant share of the 9 major automakers adhere to the standard?

As indicated, the commercial operating system solution provides a much better chance of success based on the architectural model that was employed. Specifically, ownership is maintained by a vendor that lacks value without the incorporation of the platform by both sides of the interface. They are incentivized to foster incorporation of the platform, primarily through creation of value for the stakeholders involved. If the platform is not successful, the leadership activity will suffer since there is no independent value in the operating system.

The recommendation from this study is to pursue the commercial operating system architecture as the primary method for meeting the needs of mobile device integration with the automobile. The tactical implications of such an architectural strategy can be established by using the framework compiled in this paper. The primary question has to do with how the platform leader, the commercial operating system vendor in this case, will proliferate the platform through complementor incentives?

The next task involves determining the specific stakeholders that will be involved and what role they will play in the model. Specifically, which stakeholders will choose to compete in each segment? The automaker should realize that the commercial operating system vendor may choose to compete in the application development space. The automaker should be aware of the intentions, whether to temporarily develop applications to foster the platform incorporation, or whether a longer-term approach is going to be taken to extract the most amount of value from the system. These considerations will become critical for the automaker over the long run.

7.3 Future Study

This paper establishes the framework and evaluation of two key solution proposals to the mobile consumer electronic integration need in the automobile. The intention of the paper is to provide a framework for further tactical evaluation of the solutions and further development of new proposals. In addition, although the framework was developed around a specific need, the resources used to establish the framework were generic. This means that this framework may be extensible beyond the need that is addressed in this paper.

7.3.1 Commercial Operating System Tactical Evaluation

As indicated, the commercial operating system solution provided in this paper still has many questions to be answered based on the specific stakeholders that are included. The implementation could be very different depending on the commercial operating system vendor that was chosen. From the framework we know that the role of the operating system vendor is the foster complementary innovation at the interfaces. The way in which this is done could be different depending on the specific capabilities or strategies of the operating system firm. Future study in this area would involve the anticipated behavior of the operating system alternatives. This could include a critical comparison of strengths and weaknesses with respect to the automakers of one solution over another.

7.3.2 New Solutions to the Mobility Integration

Next, the solutions presented in this paper are not meant to indicate the entire solution space that is available to the automakers. The framework established could help in identifying new solutions to the problem. These strategies should be compared with those of this paper to determine if there are additional opportunities to solve the problem. If the needs are met and the architecture is found to be appropriate, the stakeholder configuration could be found to be more optimal for platform proliferation and distributed value creation. In other words, a more mutually beneficial arrangement might be found that benefits all stakeholders.

7.3.3 Framework Extensibility

Finally, future study should involve establishing the extensibility of the framework to other areas. This study would involve finding areas with similar external interface needs that involve significant clockspeed and/or complexity gradients. This would indicate the need for an external platform, and thus lend itself to the use of the framework to establish possible solutions and tactical implications.

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