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ACHIEVING WORLD-CLASS PERCEIVED VEHICLE QUALITY THROUGH IMPROVED ENGINEERING AND MANUFACTURING TOOLS

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Achieving World-Class Perceived Vehicle Quality through Improved Engineering and Manufacturing Tools

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ABSTRACT

Throughout the vehicle development process, automotive manufacturers must work to meet a variety of customer needs. One increasingly important attribute is vehicle exterior perceived quality, which is largely dependent on how well exterior parts fit together. Before vehicles are produced and sold to customers, manufacturers utilize several processes and tools to "tune in" vehicle exteriors. This thesis examines one manufacturer's approach to delivering vehicle exterior quality, including a recent change initiative to improve the tune in process.

The overall vehicle development process is introduced, and then detail is provided for areas of the process that relate closely to vehicle exteriors. Two areas that are explored in depth are the manufacturer's tune in build strategy and a new exterior fitting fixture implementation. An assessment of build strategy is provided and a framework is proposed. The framework is based on functional build theory and Key Characteristic (KC) chains. Functional build is a process to ensure that the vehicle exterior meets specifications while allowing engineering teams to determine the best way to solve dimensional problems, which may or may not include forcing a component in the assembly to design intent. A KC chain analysis is one way to view how vehicle exterior requirements relate to each other and engineering organizational structure. Viewing build strategies with these two techniques illustrates how build decisions are impacted by organizational and technical complexity, as well as material rigidity.

At an automotive manufacturer, several fitting fixtures are used during the tune in process. An initiative to implement a new fitting fixture is assessed. Both technical and organizational issues are addressed. The conclusion of this thesis is that several factors that are both organizational and technical must be considered in order to gain the benefit of the new fitting fixture. Some of the major factors include: build strategy alignment with the fixture, learning systems to support continuous improvement, and organizational leadership and ownership aligned to quickly solve problems.

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Chapter 1 – Introduction

Competitive forces in the global automotive industry are higher than ever. Manufacturers today have to produce high quality vehicles, keep costs low, and introduce more models each year to attract consumers. As a result of these competitive pressures, manufacturers must continually examine how their product development and manufacturing processes can help achieve their objectives. This thesis explores a tool and related processes that have the potential to increase quality, reduce costs, and help enable the rapidly accelerating pace of launching new vehicles into production.

In the last two decades, as automotive competition has intensified and consumer power has strengthened, customers' expectations of quality have increased dramatically. Years ago, the definition of a high quality vehicle was one that did not require extensive or frequent service. The new quality standard is "perceived quality". Not only do customers demand a durable car, many need to feel like their vehicle is a precise machine, engineered and built with the attention to detail and fine craftsmanship of a Swiss watch.

Traditional quality has been a competitive advantage for many non-U.S. automakers in the 1980s and early 1990s. However, automotive industry metrics, such as those published by J.D. Power and Associates, have recently shown that U.S. automakers have closed the quality gap. In fact, all automakers have begun to adopt Japanese flexible-manufacturing practices, and the 2004 J.D. Power and Associates' gold, silver, and bronze awards for initial quality went to plants from U.S. automakers General Motors and Ford Motor.[1]

Quality and durability are now "must haves", and the new dimension on which to compete is perceived quality. Bob Lutz, head of General Motors Product Development and Vice Chairman, captured the essence of perceived quality in an interview with Edmunds.com:

“So the reality is we've closed the quality gap but the lag in customer perception is still huge. The average person still believes that the Japanese cars' quality and reliability is head-and-shoulders above General Motors, and it simply is no longer the case. ... Better panel fits, closer gaps, better door-closing sounds, better-tailored seat covers and more precise knobs and switches. Soft, low-gloss plastic parts instead of hard, shiny ones. All of those things are part of what the customer registers as a quality perception, which is why we call it "perceived quality." And your real quality can be outstanding, but if your perceived quality is off, the customer says, "Gee, I don't know, this is a pretty lousy-looking interior. I can't believe this is a good car.""[2]

In addition to perceived quality challenges, excess industry capacity has caused an increase in price competition. For this reason, manufacturers' investments in quality must be carefully selected, as it is difficult to recoup these investments on price hikes alone. Balancing this tradeoff is critical, and manufacturers must seek out quality initiatives that do not increase the total cost of vehicle development and production.

1.1 Thesis Objective & Research Methods

The objective of this thesis is to analyze a tool and related processes that can contribute to perceived quality of vehicles at an automotive manufacturer. While the topic of perceived quality covers a wide variety of issues, the focus of this document is on perceived quality of vehicle exteriors and how well parts such as headlamps, doors, and fenders fit together. The specific tool that will be explored is what many manufactures call an exterior vehicle fitting fixture.

To that end, the overall question this thesis will address is: “What factors, both technical and organizational, should be considered when selecting and implementing an exterior vehicle fitting fixture?” To answer this question, the author worked for approximately eight months at an automotive manufacturer that will be referred to as LaPerre Motor Company.[3] The two objectives, in addition to gathering data for this thesis, were to 1) understand the motivation and business case for a new fixture and 2) lead the pilot implementation.

While conducting the project at LaPerre, the author was fortunate to learn a great deal about vehicle exterior fitting methods, gather data from industry experts, read existing literature, and gain an appreciation for the organizational challenges inherent in change efforts at large corporations. This thesis presents a case study of LaPerre's initiative to increase exterior perceived quality by implementing a new exterior fitting fixture. The case study provides a real application of the concepts that follow and will be referred to throughout the thesis.

1.2 Hypothesis

This thesis will examine the following hypothesis: to gain the benefits of a new exterior fitting fixture at a large vehicle manufacturer, several enablers that are part of a larger system must also exist or be implemented. The key enablers that provide the necessary consistency with the new fixture are related to engineering processes and organizational capability, both internal and external, to adapt to the new processes.

1.3 Thesis Scope & Structure

Chapter 2 introduces the LaPerre Corporation in more detail, providing background on their vehicle development process. Understanding the vehicle development process and the activities involved will help the reader understand the context of the change initiative.

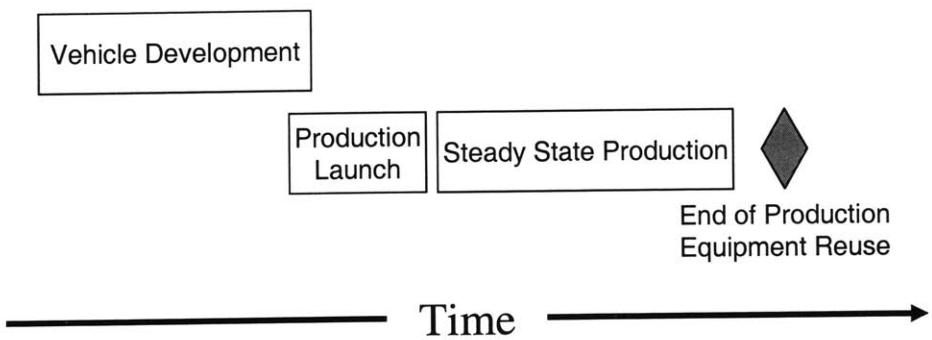
Chapter 3 introduces various types of exterior fitting fixtures, their purpose, and some of their advantages and disadvantages. Chapter 4 covers technical considerations related to overall build strategy in which an exterior fitting fixture is used. A framework is presented to aid the reader in overall understanding and application of one build strategy. This model will also be used in Chapter 5 to explain key design decisions of LaPerre Motor's new fitting fixture.

Chapter 6 will look at the effort from an organizational behavior and change leadership perspective. An assessment of the organization from a strategic and cultural perspective will be provided. Finally, Chapter 7 will provide a summary overview and concludes with recommendations.

Chapter 2 – Vehicle Lifecycle

To understand how exterior fitting fixtures are selected, designed, and used, it is helpful to look at the vehicle lifecycle from a manufacturer's perspective. One way to view the process is to break it up into phases that include vehicle development, production launch, steady state production, and end of production/equipment reuse.[4] Figure 1 illustrates this basic view of the vehicle lifecycle. The remainder of the chapter will delve into these phases, and Chapter 3 will highlight exterior fitting fixture activities within the context of the overall vehicle lifecycle.

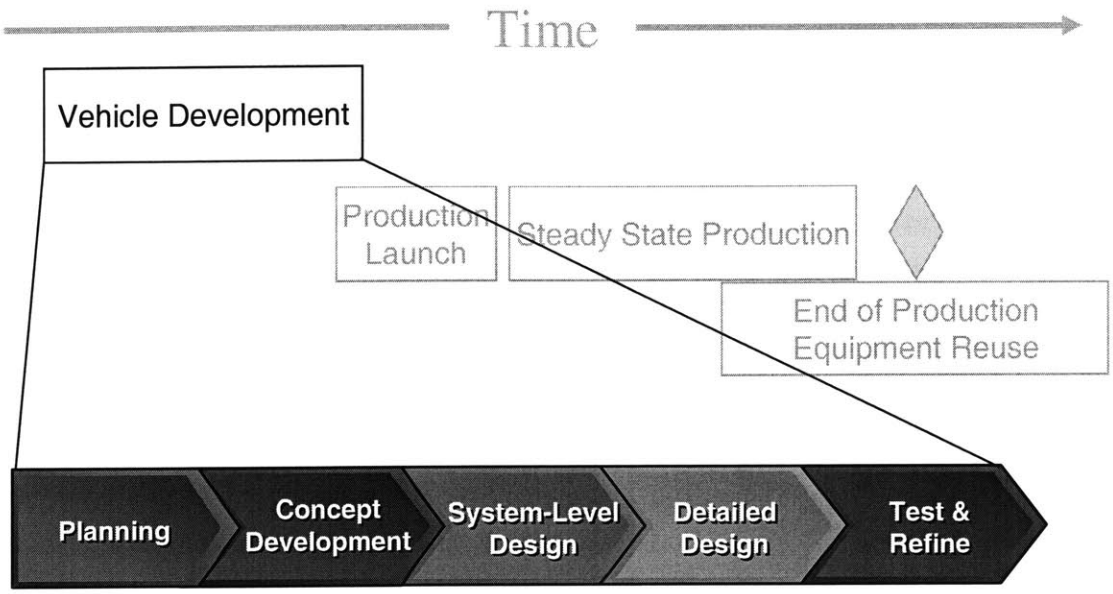
Figure 1: Overview of Vehicle Lifecycle



2.1 Vehicle Development

Like most product development projects, vehicle development includes planning, concept development, system-level design, detailed design, and testing and refinement (shown in Figure 2).[5] Although they are somewhat related to the topic of this thesis, planning and concept development will not be deeply explored. This document focuses on the latter stages of the vehicle development process, namely the system level design, detailed design, and test/refinement stages.

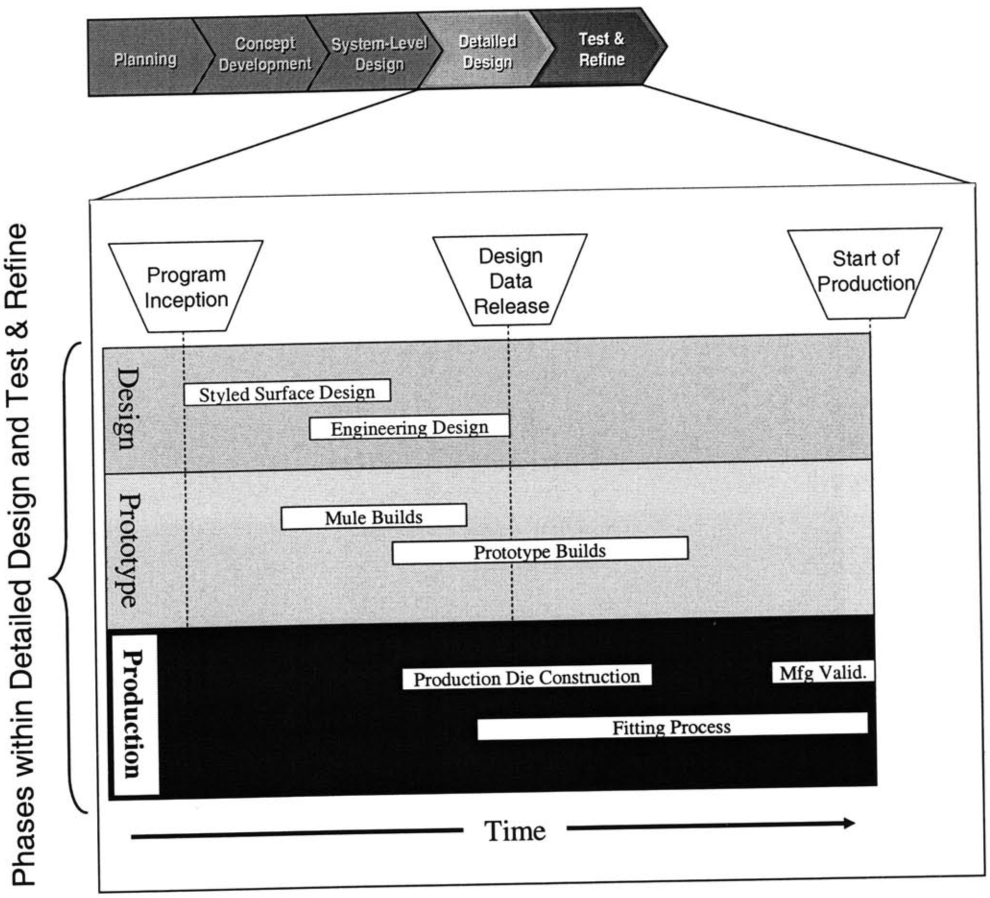
Figure 2: Vehicle Development Mapped to Generic Product Development Process



System-level design includes a design of the overall architecture and decomposition of the vehicle into major sub-systems and components.[6] Decisions in this stage begin to impact the design of the exterior fitting fixture that will be used in subsequent phases of the vehicle lifecycle.

Development activity related to the exterior fitting fixture is most concentrated in the detailed design and testing/refinement phases. During the development of a vehicle, the detailed design and test/refine stages are comprised of three workstreams: design, prototype, and production[7] and are illustrated in Figure 3.[8]

Figure 3: Detailed Design & Testing/Refinement Activities



The design workstream consists of styled surface and engineering design. Styled surfaces are the vehicle parts that the end customer sees, such as the doors, hood, and body sides. As the styled surfaces are being finalized, engineers begin designing all of the components and structural surfaces of a vehicle. The majority of this design work is completed in a Computer Aided Design (CAD) environment, and the final math-based files are released in stages based on production tool lead-time requirements. The purpose of the staged release is to allow dies to be started as soon as possible, as opposed to waiting for the entire vehicle to be completed. Many of the components that are eventually mounted to an exterior fitting fixture, such as the body sides, hood, and fenders, are the last to have fabrication tools kicked off.[9]

While surface and component design is in the fine-tuning stage, prototypes are constructed and vehicle level development such as ride/handling is conducted. Prototypes are complete vehicles that are built before mass-production tools are available.[10]

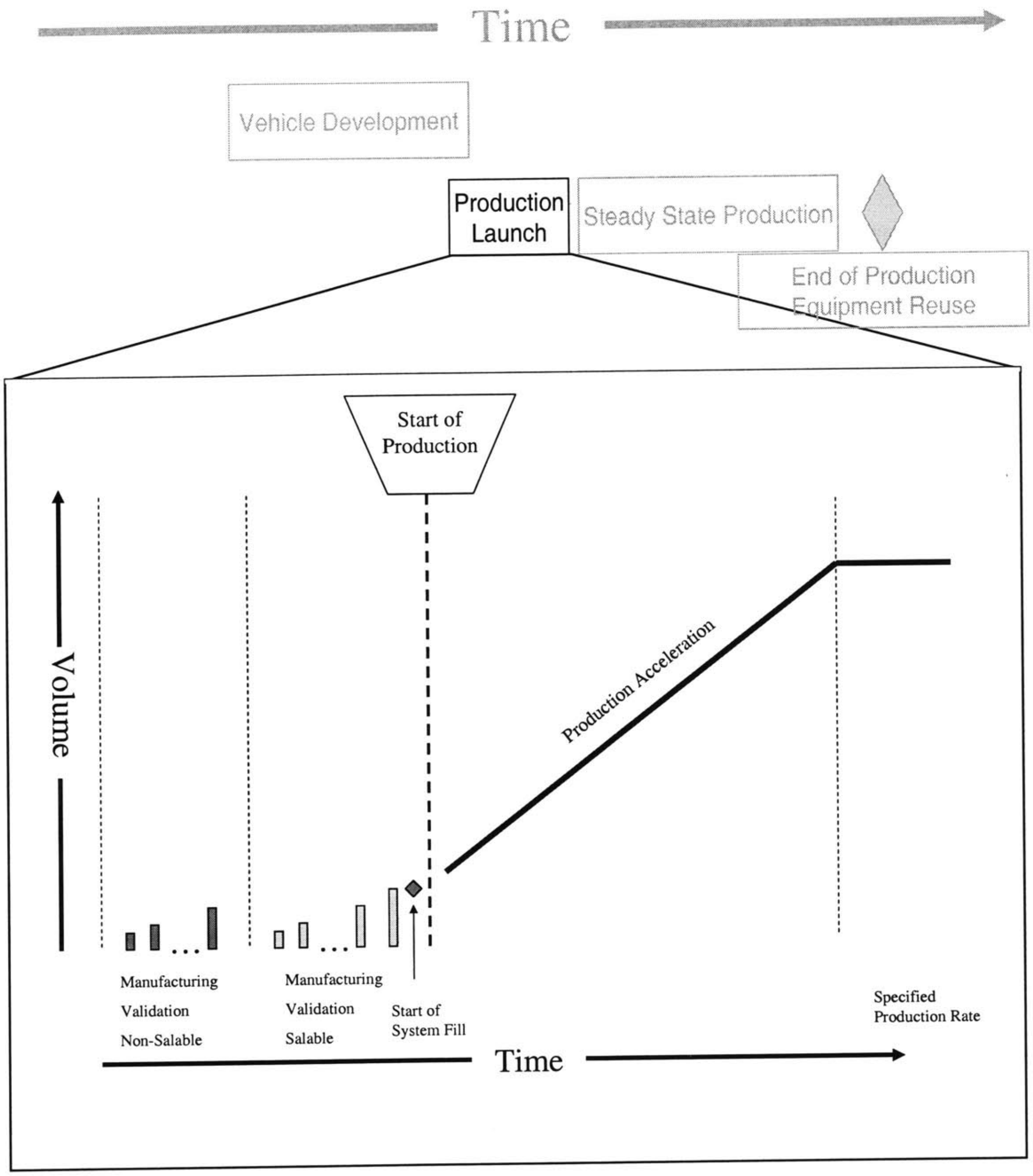
The production workstream begins when metal stamping dies, molds, and other production tools are fabricated. As each die is completed for the first production parts to be stamped and/or assembled, the engineers attempt to reach a stable process within close range (approximately 3/4 of points measured) of specifications. Next, a fitting process is used to "tune-in" the production tools and dies. As production parts are produced, they are evaluated for functionality, and dimensional precision and accuracy. For exterior parts, this "tune-in" process benefits greatly from an exterior fitting fixture. More on this subject is included in Chapters 3 and 4.

The fitting of parts can also continue into the vehicle assembly process validation stage, where manufacturing tools are also "tuned-in". At this point, the dies are typically the "home line", where they will remain for regular production. For the initial assembly events, LaPerre uses a pre-production facility and supplier facilities to begin the fitting process, and eventually moves the fitting activity to the vehicle assembly plant as manufacturing validation is ramped up. When the assembly plant starts running and approaches the start of production date, the production launch process is initiated.

2.2 Production Launch

Toward the end of the vehicle development process, the manufacturing validation non-saleable production begins, followed by manufacturing saleable, start of system fill, and production acceleration. Although many other activities take place, a simplified version of these stages is depicted in Figure 4.[11]

Figure 4: Overview of Production Launch Process



The goal of the launch process is to prepare the plant personnel and equipment for regular production at a pre-determined rate of vehicles per day. Typically, the first vehicles built are considered non-saleable. That is, they are built with production tools and processes but do not meet the quality standards required to sell the vehicles to consumers. The following build – manufacturing validation saleable – is for vehicles that can be sold to consumers, assuming that any major issues from the non-saleable batch were resolved. During non-saleable builds, a small number of exterior fitting issues are typically being resolved, and minor continuous improvements to the exterior may continue into subsequent stages.

When the start of system fill is initiated, the vehicle development process is effectively complete, and all of the required raw materials, sheet metal, and subassemblies fill the supply pipeline that extends from each station in the assembly plant to supplier facilities to material sources. Movement of that material is increased as the rate of vehicle production is ramped up. Upon completion of ramp-up, the line runs at a specified production rate, and the launch process is complete.

2.3 Steady State Production & End of Production

Steady state production is commonly referred to as "regular production". At this point, the focus is on continuous improvement and resolving any potential issues that may arise from unexpected equipment issues or supplied material defects. Regular production typically extends for several years until production is discontinued or additional options and features are added to the vehicle. At the conclusion of the vehicle's production life, much of the equipment, including exterior fitting fixtures, is recycled or reused on future vehicle programs.

2.4 Chapter Summary

This chapter provided an overview of a generic vehicle development process. It divided the process into vehicle development, production launch, steady state production, and end of production/equipment reuse. Throughout each of these phases, different activities take place that impact the quality of vehicle exterior fits. This understanding of the overall process provides a structure in which to introduce more detailed processes and tools discussed in Chapter 3.

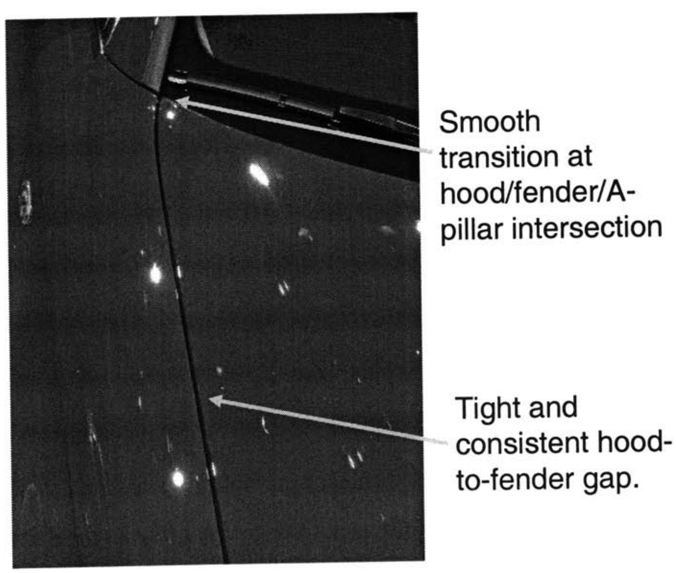
Chapter 3 – Exterior Fitting Tools & Processes

In order to understand an engineering system that utilizes an exterior fitting fixture, it is helpful to understand their purpose and how they are used. This chapter also lays out some of the challenges inherent in vehicle dimensional management.

3.1 Purpose of Exterior Fitting Tools

The primary objective of exterior fitting tools is to verify and ensure that exterior dimensions that consumers care about most are within an acceptable range. The exterior dimensions that are considered critical are all part-to-part interfaces that a customer would see. For example, the gap between a hood and fender is shown in Figure 5. The consistency and closeness of the gap projects an image of craftsmanship that is required to excite many customers and to compete in large segments of the automotive market. Another feature that is important to the look and feel of the vehicle's quality is alignment of mating parts. Figure 5 shows how good alignment at the intersection of the fender, hood, and A-pillar contributes to the overall flow of the vehicle's shape. For this reason, the gaps between parts are measured and tracked closely throughout vehicle development and production.

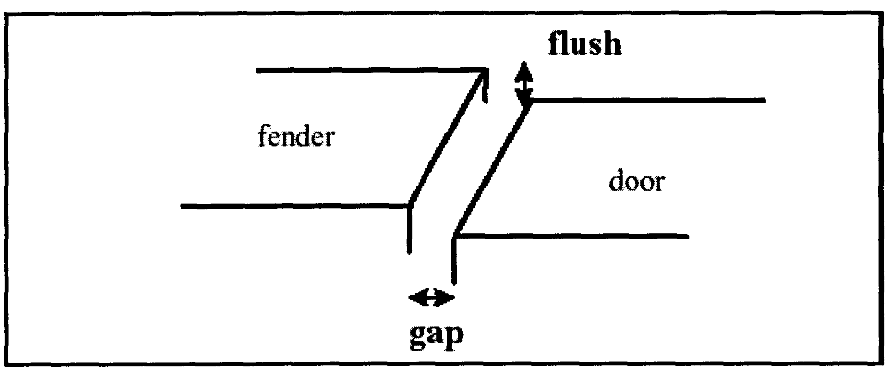
Figure 5: Example of Excellent Hood-to-Fender-to-A-pillar Fit



Several categories of dimensions exist. However, gap and flush are what many customers notice. This widely accepted view on exterior fits is summarized in this Quality Magazine quote: "The size of the gaps between body panels such as the hood and fenders, fenders and doors or deck lids and quarterpanels are increasingly scrutinized by consumers. The flushness of adjacent body panels is closely examined as well. These body fit characteristics not only affect customer perceptions of vehicle quality, but they also affect warranty claims for issues such as water leaks and wind noise."[12]

Lee and Thornton use the term *Key Characteristics* (KCs) for product features, manufacturing process parameters, and assembly process features that significantly affect a product's performance, function, and form.[13] Gap and flush of vehicle exterior parts are Key Characteristics, and warrant special attention throughout the development process. Figure 6 provides a sample illustration of gap and flush.[14]

Figure 6: Gap & Flush Illustration



At LaPerre, tolerance ranges for gap and flush are specified early in the vehicle development process and are followed closely throughout the vehicle lifecycle with both computer aided design tools and fixtures. Before examining LaPerre's change initiative, Section 3.2 will explore general methods to track and measure dimensional progress of a vehicle throughout the vehicle lifecycle.

3.2 Exterior Dimensional Tools

Exterior dimensional tools can be divided into four main categories: 1) virtual (CAD) tools that verify design, 2) measurement tools that take a sample of discrete measurements or scan entire parts to verify dimensions with a computer representation of physical parts, 3) online production laser gauges, and 4) fixtures (exterior fitting) that allow measurement and/or visual evaluation of physical parts.

CAD tools are widely used to both execute and verify design intent. For example, at General Motors, a virtual build event to evaluate assembly interfaces is completed before physical prototypes are available.[15] The second category of dimensional tools is a combination of physical and virtual spaces, in that actual parts are scanned and either evaluated against the part's CAD model or assembled with other scanned parts in a computer environment.[16] Online production gauges have historically been physical measurement fixtures, but today consist mostly of laser gauges that help monitor dimensional variation during production. This thesis focuses on earlier stages of the vehicle lifecycle, where both CAD and other virtual tools are extensively used today. As computer-based tools mature, the need for fitting fixtures may decrease in the future. However, today (and likely for several years to come), fixtures provide significant advantages and continue to be a critical component of successfully developing and launching vehicles at LaPerre.

Exterior fitting fixtures are used to evaluate Key Characteristics of exterior parts, such as panel-to-panel fit (e.g., door-to-fender, door-to-door) and interfaces between parts such as lamp-to-hood and lamp-to-fender gaps. As production dies are fabricated, an iterative process is used to "tune-in" the dies and/or assembly tools to produce parts that are dimensionally acceptable (i.e., deliver the appropriate Key Characteristics). Detail fixtures are used to measure components at stamping facilities and other supply houses, and assembly check fixtures are built to measure dimensions of subassemblies such as a door or hood. What makes a fitting fixture unique, however, is its focus on the Key Characteristics of gap and flush on the vehicle, whereas other types of fixtures focus on the measuring or assembling of components and subassemblies.

The importance of having a tool like this can be illustrated through an analysis of the Key Characteristics of a vehicle exterior. To start, consider the KC of the gap between a front and a rear door of a vehicle shown in Figure 7. The KC can be illustrated in a simple diagram, with the double (red) line representing that a KC relationship exists between the front and rear doors.[17] If during the fitting process the gap is initially too small, the front door could be adjusted forward. However, moving the front door forward will impact the gap between the front door and the fender. The case where addressing one KC impacts another is called a Key Characteristic *conflict.*[18] This conflict is shown in Figure 8. According to Whitney, one way to resolve a KC conflict is to alter the assembly sequence. Typically, automotive exteriors are built from the back forward, which in this case might seem to resolve the KC conflict by allowing the assembly process to simply shift the fender forward. The fender is adjacent to several other parts, however, with additional and highly integrated Key Characteristic relationships that are shown in Figure 9.

Figure 7: Front to Rear Door Gap Key Characteristic

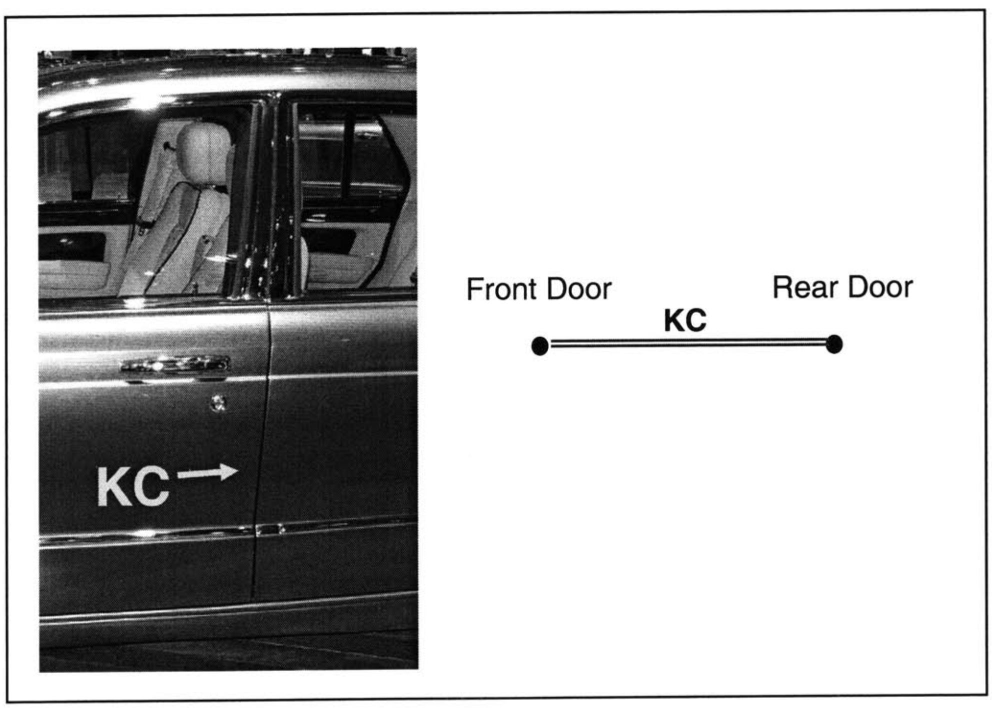


Figure 8: Key Characteristic Conflict

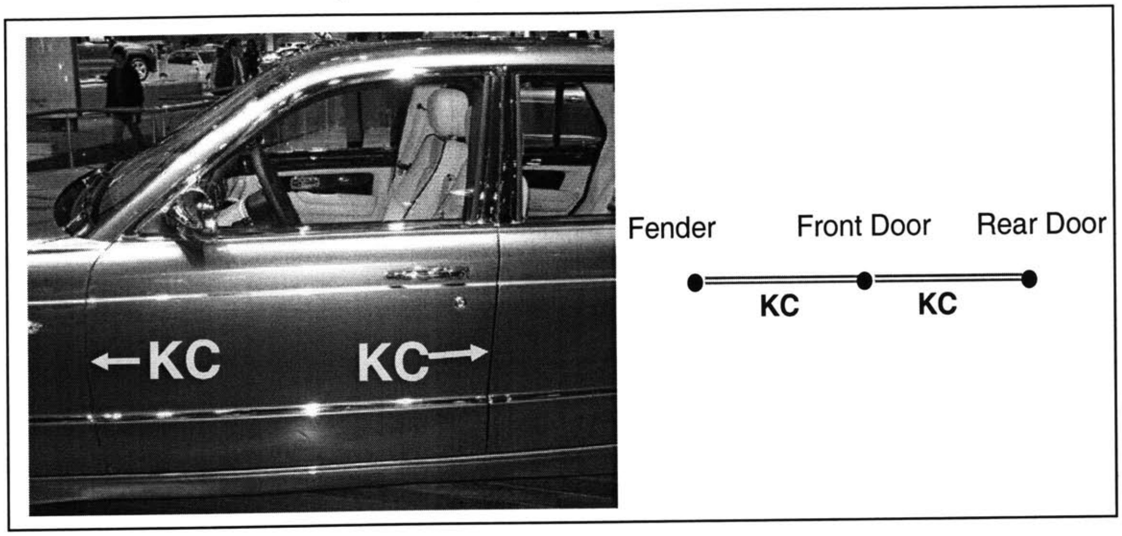
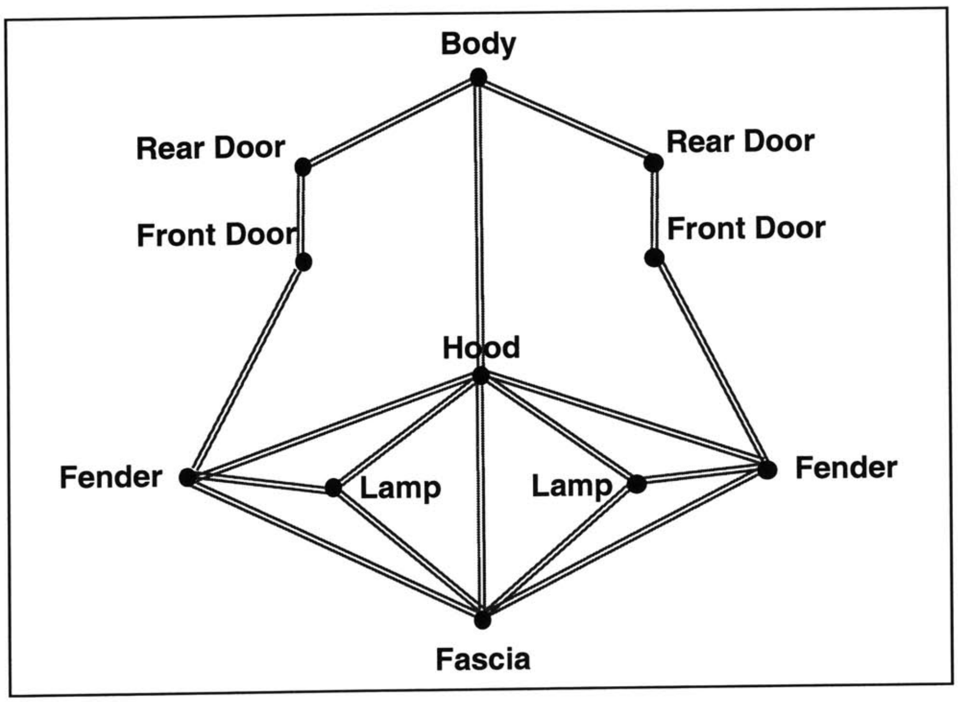


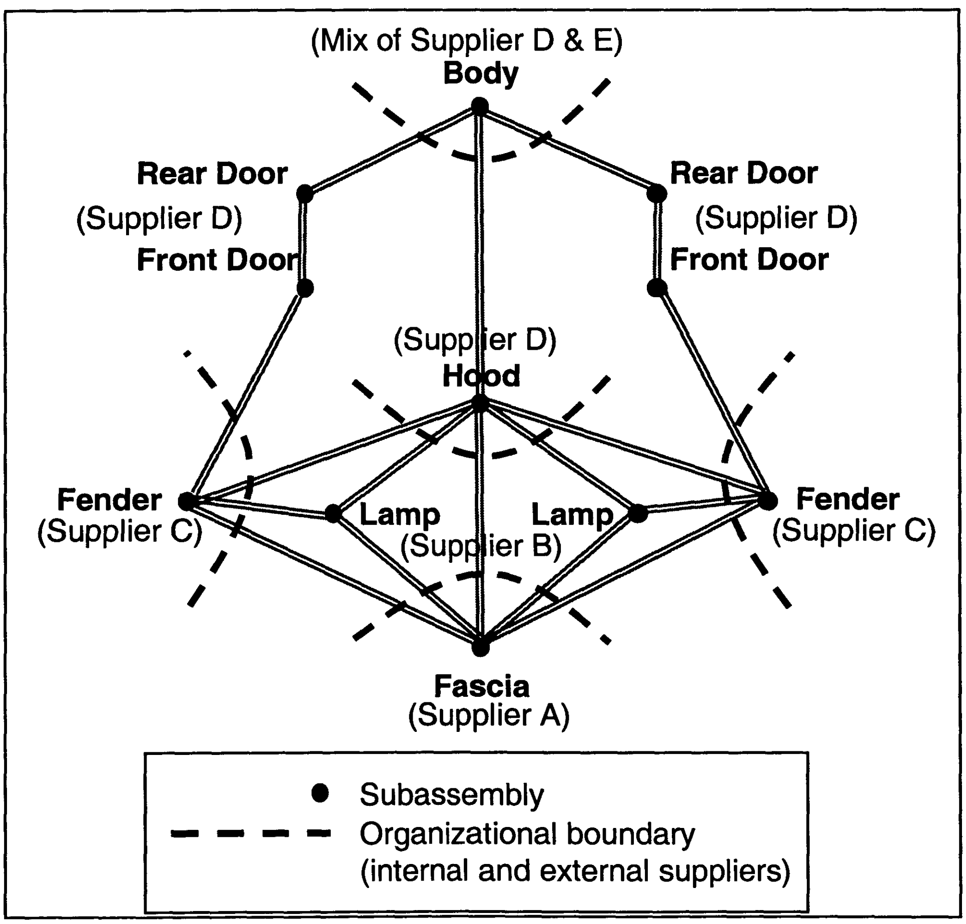
Figure 9: Vehicle Key Characteristic Conflicts



It is not possible to solve the KC conflicts in Figure 9 with any assembly sequence. If the front door is too close to the fender, moving the fender will impact three other KCs. The cycle continues and any variation that is transferred along the chain will impact multiple KCs. This is perhaps one reason why auto manufacturers cite numerous vehicle launch issues related to lamp fits. Complicating the matter even further is the part-to-part flushness requirement, a second KC between the same KC nodes in Figure 9 that may be in conflict with gap KCs.

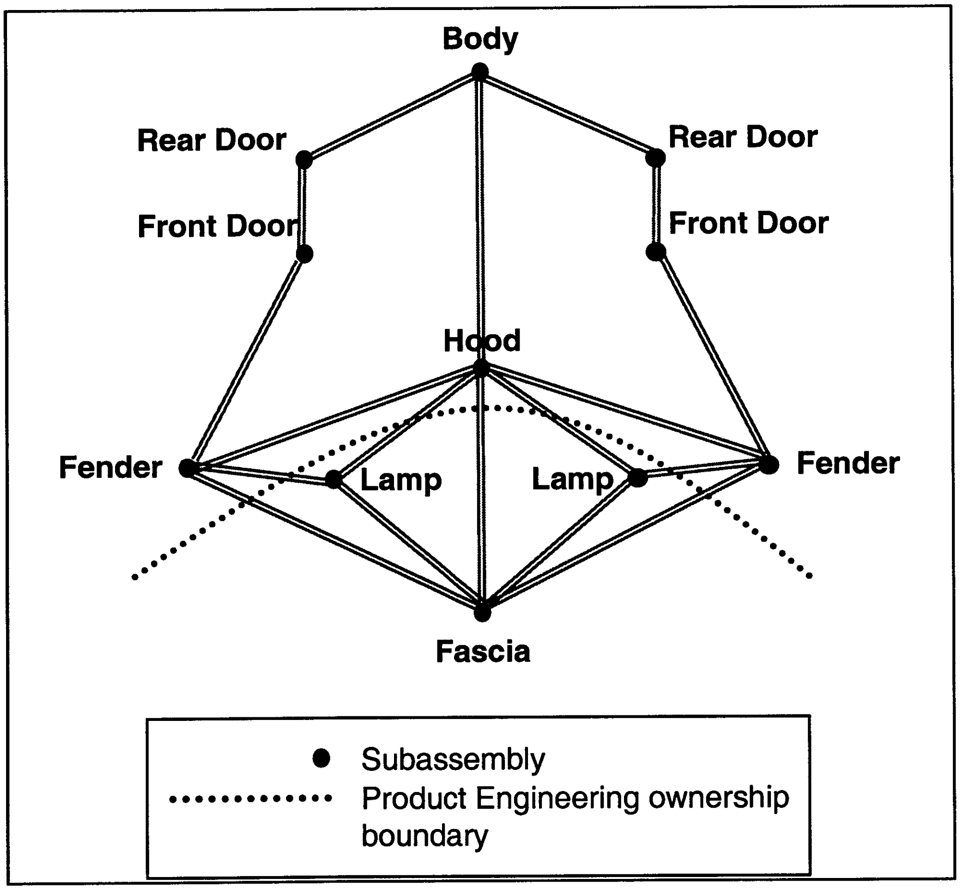
The supply chain of each subassembly and their respective components increases the difficulty of ensuring all KCs are delivered. At LaPerre, the doors, fenders, and hood are supplied internally for most vehicles, and different venders are used for lamps, fascias, and often times assembly fixtures for each exterior part subassembly. This makes resolving potential design and quality problems more difficult during validation and launch phases, because each supplier is focused more on their own parts than the entire assembly. This fragmentation is shown in Figure 10.

Figure 10: KCs that Typically Cross the Supply Chain



KCs that cross organizational boundaries increase the challenges of coordination. Perhaps an even greater management challenge arises from segmented ownership. In the past, KC design ownership at LaPerre was not allocated to a single person until very high levels of management. This engineering ownership boundary is illustrated in Figure 11.

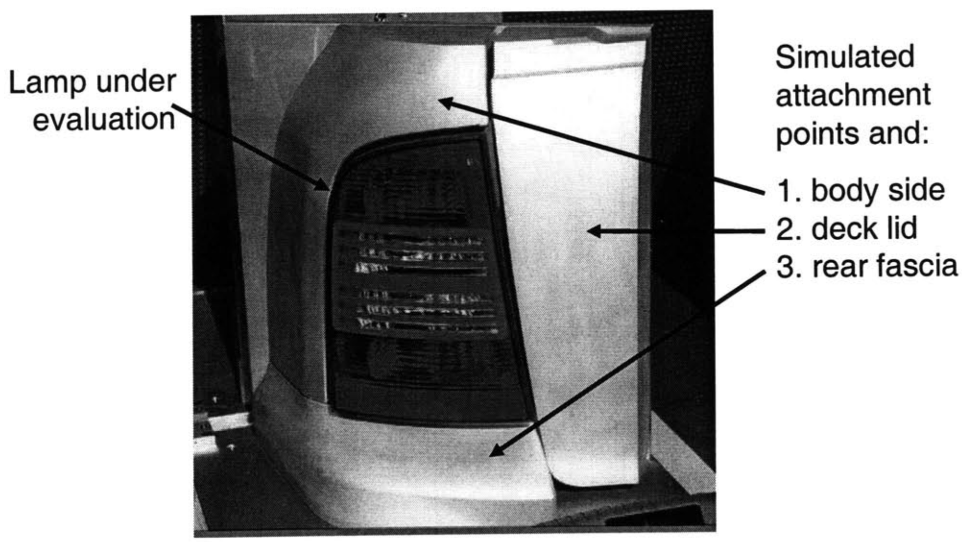
Figure 11: Product Engineering Ownership Boundaries across KCs



This investigation into gap and flush characteristics has shown that vehicles are very sensitive to dimensional errors, because significant errors can propagate throughout the vehicle's system without an available "exit" from the KC chain. Identifying and isolating potential KC fit issues early is critical to successfully launch a new vehicle. The use of a fitting (cubing) fixture can help facilitate this process.

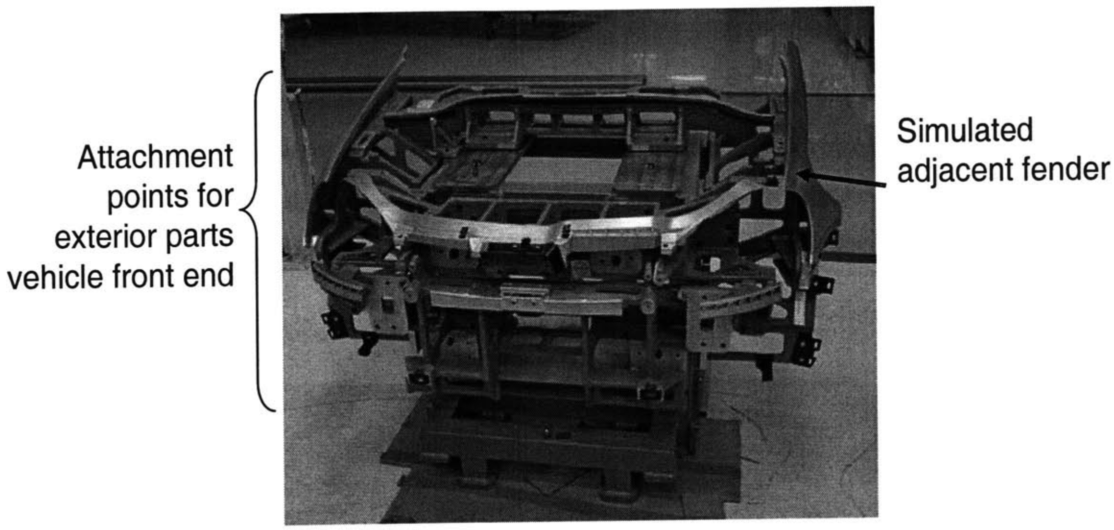
Exterior fitting fixtures enable the "tune-in" process by simulating nominal attachment points for certain subassemblies, and also may include a simulated portion of the surfaces adjacent to the subassembly under evaluation. For example, Figure 12 shows an exterior fitting fixture to evaluate the KCs around a single tail lamp from a Skoda Octavia Combi.[19] The manufacturer of this fixture refers to it as a *single-purpose* cubing fixture, and the cost is estimated at \$20K – \$40K.[20] The single-purpose cube allows evaluation of how well a lamp fits with simulated surfaces that are adjacent (e.g., deck lid, body side, and fascia). The precision-machined aluminum parts represent design-nominal and are referred to as *control* parts. The advantage of this tool is that one can evaluate Key Characteristics such as gap, flush, and overall appearance visually and follow up on any potential issues with a measurement gauge. A single-purpose cube does have limitations in that it only looks at one part in isolation, which represents only one side of the gap.

Figure 12: Single Part Exterior Fitting Fixture



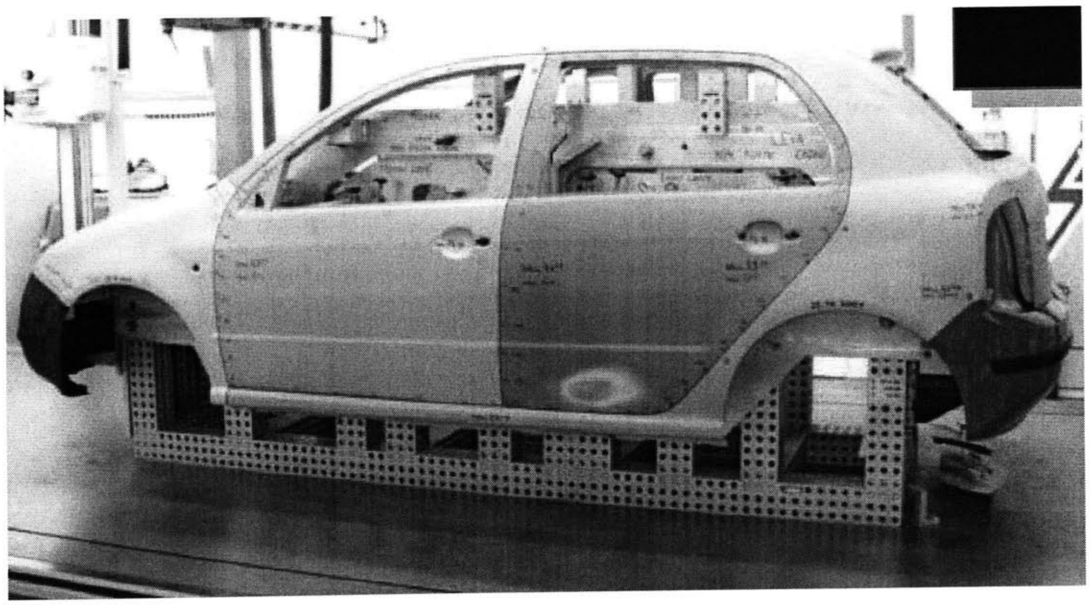
Similar to the single-purpose cubing fixture is another type of exterior fitting fixture that is larger and contains provisions for more than one production part. One fixture vendor calls this a *partial* cubing fixture, and the cost is estimated at \$200K – \$400K.[21] It includes, for example, attachments for production parts for the entire front end of a vehicle (e.g., lamps, fascia, etc.). A partial cubing fixture contains machined aluminum control parts that interface with the periphery of the rear end of the vehicle. An example of a partial cubing fixture used in the exterior fitting process for a Volkswagen Golf is shown in Figure 13.[22] In Figure 13, the partial cubing fixture is also equipped with control parts than can be interchanged with production parts. Therefore, gap and flush can be evaluated between production parts (part-to-part) or between production parts and control surfaces (part-to-control).

Figure 13: Partial Cubing Fixture – Front End



A similar concept can be extended to a fixture representing the full exterior of a vehicle. This thesis will refer to this type of fixture as a *vehicle* cubing or fitting fixture, and an example is depicted in Figure 14.[23] The cost of a vehicle cubing fixture can be as low as \$250K and as much as \$1,300K with a complete set of control parts.

Figure 14: Full Vehicle Cubing Fixture



3.3 Pros and Cons of Exterior Cubing Fixtures

Given that cubing fixtures can cost over a million dollars, why would automakers use them? The answer is that it allows visual evaluation of Key Characteristics as soon as the first production parts are available. Key Characteristics are often in conflict with each other and involve multiple organizations within auto companies and across organizational boundaries into the supply chain (see Figures 10 and 11). Many detail part and subassembly fixtures are used in vehicle development and production, but a cubing fixture focuses product development and manufacturing teams on what matters to customers in terms of exterior fit, and ultimately perceived quality.

Historically, a high number of difficult vehicle launch issues are related to gap and flush or "part fit" Key Characteristics.[24] A fitting fixture can reveal problems that would cost exponentially more to solve in later stages of vehicle development and production launch. If fitting fixtures were not available to engineering teams, they would have to wait for a dimensionally acceptable body structure (i.e., exterior part mounting points) to even begin visually evaluating exterior fits. This would come so late in a vehicle program that, with today's aggressive launch schedules, the start of production would likely be delayed. By providing a root-cause finding tool for dimensional issues, cubing fixtures speed up the iterative problem solving required to produce fabrication tools and setup assembly lines.

In conjunction with exterior fitting is a process whereby sheet metal subassemblies, and eventually an entire body, are fastened together with screws. These bodies are commonly referred to as "screw bodies".[25] The screw body build also enables dimensional evaluation earlier in the production development process, before production weld tools are ready. Throughout the screw body evaluation, comparing results from the screw body to a cubing fixture can help isolate the root cause of dimensional deviations. Cubing fixtures can also be used for problem solving in later phases of development and regular production.

The disadvantage of exterior fitting fixtures is mainly cost, which includes more than just the initial design and construction costs. Because cubing fixtures are designed and built while some of the vehicle design is changing – albeit to a lesser extent than early development phases – the fixtures themselves must be maintained to stay current with the vehicle design. In addition to the added cost of fixture modifications, project management time is required to track and manage changes to cubing fixtures.

3.4 Chapter Summary

This chapter presented the concept of Key Characteristics, challenges of managing KCs, and three types of fitting fixtures to help evaluate vehicle exterior KCs. The main vehicle exterior KCs are gap and flush. The three types of fitting fixtures are single, partial, and vehicle cubing fixtures. Several pros and cons of each fixture were also discussed. These fixtures are one piece of what it takes to successfully deliver vehicle exterior KCs. The issue is that KCs are interrelated and often times conflict if adjustments are needed. Also, because the KCs represent the interface between parts rather than the parts themselves, ownership management of the KCs can be challenging. This understanding, combined with the awareness of different build strategies in Chapter 4, helped the author to better evaluate and contribute to the fitting fixture initiative at LaPerre.

Chapter 4 – Build Strategies

A build strategy is the process that automakers devise to validate, buyoff, and launch an assembly process for a new vehicle. Over the past 20 years, much attention has been paid to the build strategies used by Japanese companies. Global competitors, especially in the U.S., have worked to learn Japanese build strategies in an effort to improve their own systems. As a result of this research by U.S. companies, two broad categories of build strategy have emerged as common language at automotive companies. The goal of this chapter is to explain the two philosophies, as they impact design decisions of exterior fitting fixture. An understanding of these strategies will also help to shed light on some of the challenges auto manufacturers including LaPerre have faced (detailed in Chapter 5) in their continual quest to launch high quality vehicles faster and at lower costs.

4.1 Net (nominal) Build Philosophy

Net (or nominal/build-to-print) build philosophy is the more traditional of the two build strategies, and is conceptually simpler to understand and manage with business systems. The traditional approach to ensuring assemblies meet a certain dimensional specification is to first validate that each component and subassembly produced meets design specification. Stated simply, perfect parts (i.e., close to nominal and in the tolerance band) should assemble into perfect assemblies in a net build world. One key assumption to this, however, is that the component parts are rigid, and therefore their dimensions are not changed by the assembly process.

In the automotive industry, component parts are not all rigid. According to one research study, 37% of vehicle assembly processes involve non-rigid parts.[26] Therefore, dimensions of many parts change as they are seated into fixtures, clamped, and then welded. Also, while the net build approach is easier to conceptually understand and manage with engineering approval systems, history has shown that this approach can make it difficult, if not impossible, to meet timing and cost objectives. Critics point to the fundamental flaw that net build focuses decisions on optimizing parts, rather than assemblies that customers ultimately see.

4.2 Functional Build Philosophy

Over the last decade, Daimler-Chrysler Corporation, Ford Motor Company, and General Motors Corporation have studied the functional build strategy based on learnings from other automakers.[27] LaPerre Motor has also implemented a functional build approach at various levels of the organization. This section summarizes the main elements of functional build as outlined by the Auto/Steel Partnership Program, the University of Michigan Transportation Research Institute's Office for the Study of Automotive Transportation, and the Author's research at LaPerre Motor.

Functional build takes a holistic approach to validating, approving, and launching manufacturing processes for new vehicles. Rather than focusing on getting 100% of the components within design specification, this approach focuses on consistently building acceptable assemblies, as defined by Key Characteristics. If the mean values of most component parts are within design specification, the theory is that the ones out of specification might not negatively impact the dimensional quality of the vehicle assembly. Another aspect of the functional philosophy is to consider all options that will accomplish the goal of making a good assembly, not just reworking all dies for components that do not meet specifications. There are several reasons why the components that do not meet specification could still build into an acceptable higher-level assembly.

First, the design and assembly process could be robust enough to absorb variation. Two parts joined with a slip plane is an example and is shown in Figure 15. If one part is longer than expected, the overall length remains the same if assembled with the fixture shown. Another possibility is that, because several automotive assembly processes involve non-rigid components, parts are deformed into place such that the assembly containing the "bad" part becomes dimensionally acceptable. An example of this is shown in Figure 16.[28]

Figure 15: Slip Joint

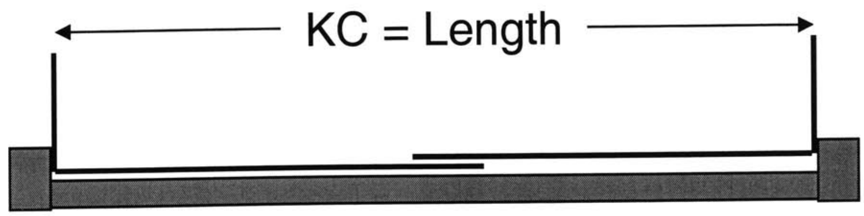
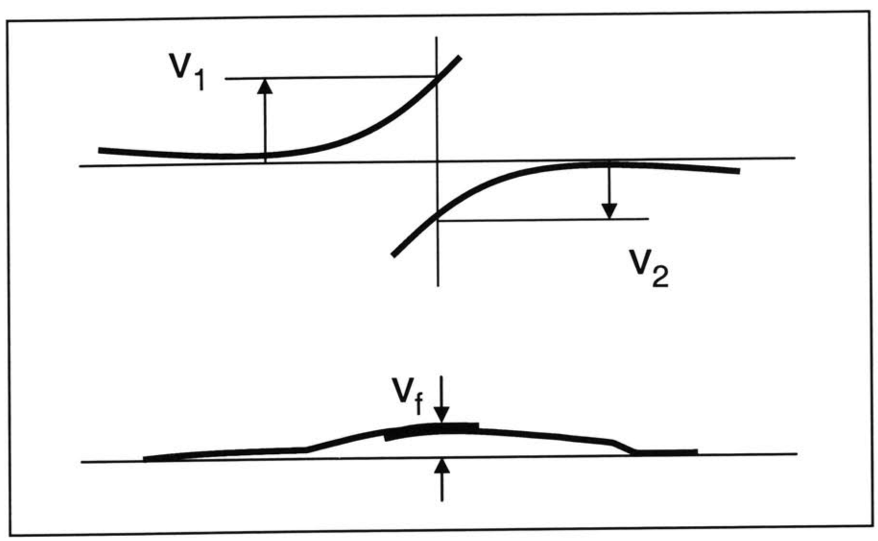


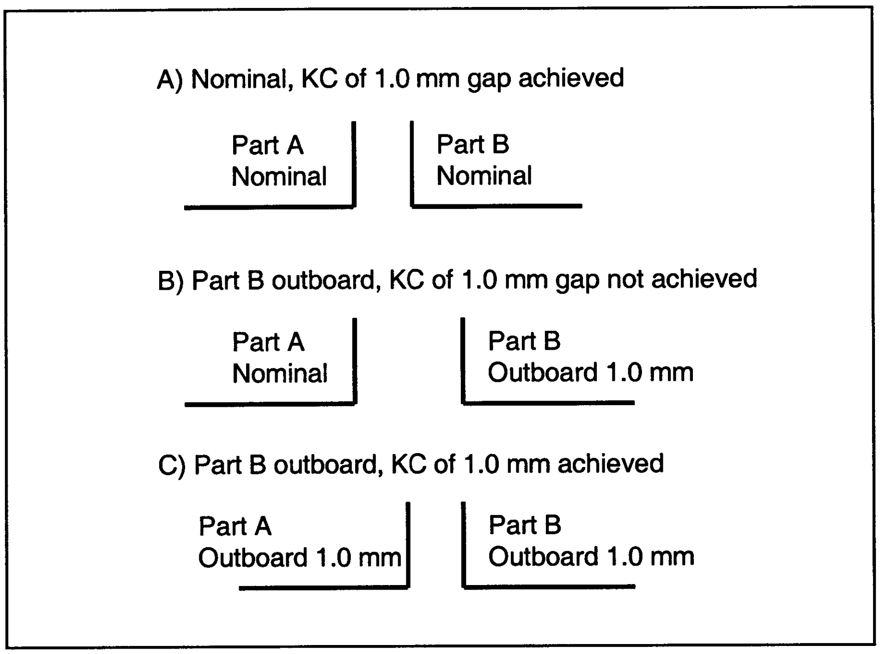
Figure 16: Assembly of Non-Rigid Components



With a functional approach, part one and part two from Figure 16 are assembled with a screw fastener or weld, and if the final variation V_f is within the assembly specification, the dies for part 1 and 2 are not reworked. This is the case even if variations V_1 and V_2 do not lie in the specified tolerance band on their prints. In a functional build mindset, rather than asking if the component dies can be reworked, the relevant question is whether the stampings will repeatedly make similar parts and whether the assembly process can consistently fasten them with similar results. However, if a net build approach is used, both V_1 and V_2 are treated individually. If they do not meet the specification, the dies are reworked, adding potentially unnecessary time and cost in the fitting process.

A third scenario is where a dimensional discrepancy may require some die rework, but engineers have flexibility in which part to modify. For example, Figure 17[29] shows the Key Characteristic of two weld flanges in an assembly that should ultimately have a gap equal to 1.0 mm. For simplicity this example will assume a tolerance band of zero. A nominal outcome is depicted in case A.

Figure 17: Illustration of Functional Build



Now, let's assume that the dies fabricated the parts such that part B is outboard 1.0 mm as show in case B. The KC is 1.0 mm away from the target value. With a net build approach, the die for part B would be reworked. With a functional approach, however, several options exist. One is to choose the die with the lower rework cost or shorter lead time. Case C shows the result if the most efficient one to rework were the die for part A. Another potentially feasible solution to case B is to adjust assembly tooling to move either part A, B, or both inboard.

A fourth functional build scenario is where case C in Figure 17 happens by chance and is repeatable. That is, two errors effectively cancel each other out and will continue to do so in a stable process. As with all cases where a deviation in a component is accepted however, care must be taken to understand potentially negative impacts to the assembly process or other areas of the system in which the part is utilized. This requires communication with and approval from downstream users.

4.3 Functional versus Net

The Net build approach was challenged by the U.S. auto industry when research in the late 1980s at Japanese automakers suggested that reworking every die to produce perfect components was not the most cost-effective approach, nor did it guarantee a high quality assembly.[30] Net build was considered high-cost because it drove unnecessary and expensive die rework. Often times, adjusting assembly tooling is viewed as lower cost, and sometimes no adjustment is even required.

Functional philosophy is very pragmatic, in that it asks the relevant question of whether a component has the *potential* to build a correct subassembly, or whether a subassembly has the *potential* to build into a correct assembly. At the same time, functional decisions involve very complex systems and can require more subjective judgment. Net build is very objective and therefore conducive to a system of checks and balances that is fairly straight forward to manage once established. Functional build requires close coordination across multiple assemblies. Coordination within the organization is also needed. Documentation often becomes out-of-date, and without involvement from the original design engineers, opportunities to learn and improve future designs are lost.

Increasingly, another problem has arisen at LaPerre related to coordination of functional decisions. As the number of models from each manufacturer increases, more and more parts and subassemblies are shared across different vehicles. For example, a door that is used on one sport utility model may also be used on three other SUV models, saving design and manufacturing costs. Functional decisions made on the door subassembly of one model might not be appropriate for the other three. Compounding the issue is the lack of or sometimes inadequate documentation to track what and why functional decisions are made. Key Characteristic tradeoffs involving functional decisions on one vehicle are complex enough without having to consider how KCs may be impacted on completely separate vehicles that will be built in the future.

Organizationally, functional decisions extend across several areas of expertise, such as body shop tooling, hemming, dies, and fixtures. Functional decisions for a vehicle also extend to other subsystems such as lamps, grilles, fascias, and glass. Many of these subassemblies even cross over to other organizations in the supply chain. In many companies, engineers are often encouraged to specialize and stay in one area for long periods of time, if not for their whole career. These engineers that have specialized so deeply may be ill-equipped to make sound functional build decisions.

From a timing standpoint, it is unclear if the functional build approach is superior to net build for all vehicle programs. Proponents of functional build, such as Center for Automotive Research (CAR) members, compare the long lead time of reworking dies to the shorter timeframe of making assembly adjustments in the body shop.[31] One study by a different group at the University of Michigan found that die tryout time (part of the die construction and fitting process in Figure 3) can be reduced up to 90%.[32] Researchers that advocate the virtues of functional build do admit there are tradeoffs. They point to the inherent drawback of functional build in that it is a downstream activity, because all components in an assembly (i.e. the entire KC chain) must be manufactured before the functional build can take place.[33]

4.4 A Build Strategy Framework

In this section, a framework is proposed to summarize how functional build decisions may be applied. Another goal of the framework is to communicate how functional build is related to product structure. Finally, this model can also help to explain key design decisions for an exterior fitting fixture at LaPerre.

Before exploring functional build decisions, it is helpful to summarize the four functional build scenarios as show in Table 1.

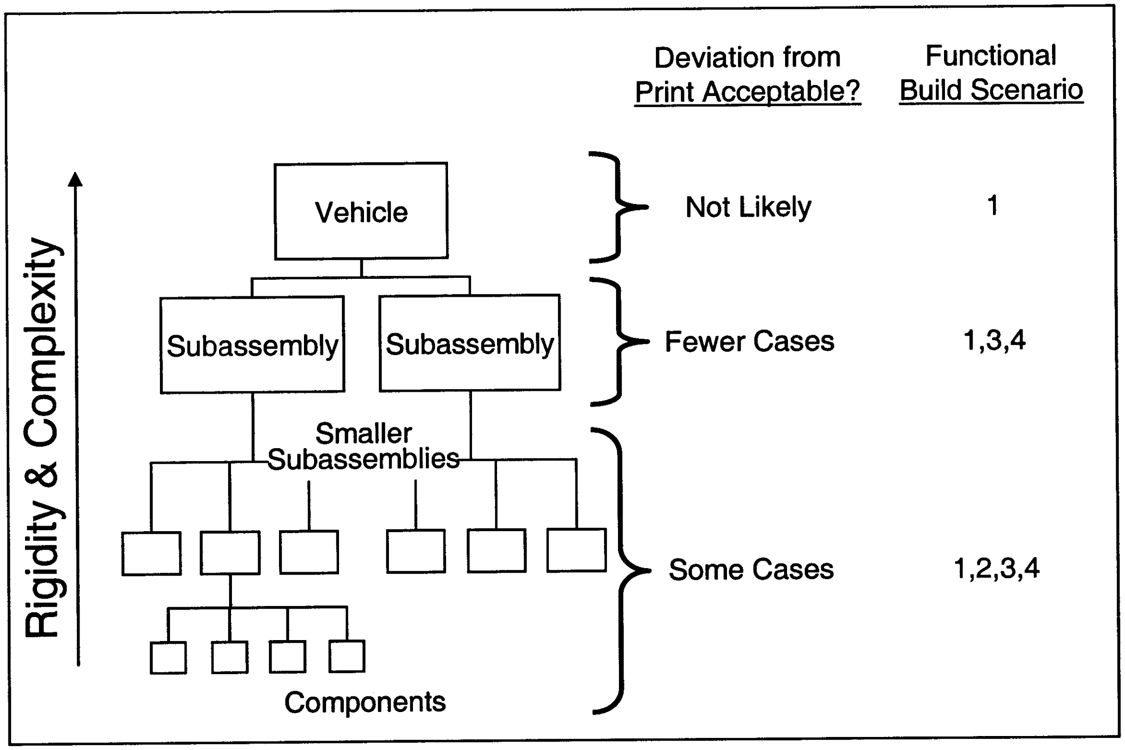
Table 1: Functional Build Scenarios

Build Scenario	Description
1. Robust Design	"Out of spec" condition does not impact Key Characteristic
2. Non-Rigid Parts	Assembly process deforms the parts back into specification or an assembly conforms to non-rigid parts enough to meet KC requirements of assembly
3. Efficient Solution	Error impacts KC of assembly, but have flexibility in choosing which die or assembly tool to change
4. Luck	Errors cancel each other out

All four scenarios are based on the assumptions that the assembly process can either absorb or compensate for a part that is originally out of the designed tolerance band, and that the consumer cares about getting a good assembly, not necessarily a vehicle with parts that are made exactly to an engineer's print.[34] By common sense, the latter assumption is likely true, the former is not as easy to assess.

Recall that in order for an assembly process to absorb mean deviations of components or subassemblies, parts must be compliant or contain slip-plane joints. Some sheet metal components are neither rigid nor designed with slip planes, and the net build approach is most appropriate. Similarly, if gross errors are discovered in stamped components, then it is clear that dies should be reworked. Perhaps a less clear application of which build strategy to take is when non-rigid components are assembled and become a more rigid structure as a subassembly. As rigidity increases, the ability of the assembly process to absorb mean deviations decreases. The framework presented in Figure 18 illustrates this concept. The model applies to sheet metal, and although other parts have not been the focus of most build strategy literature, the framework also encompasses lamps, trim parts, and other exterior parts or assemblies.

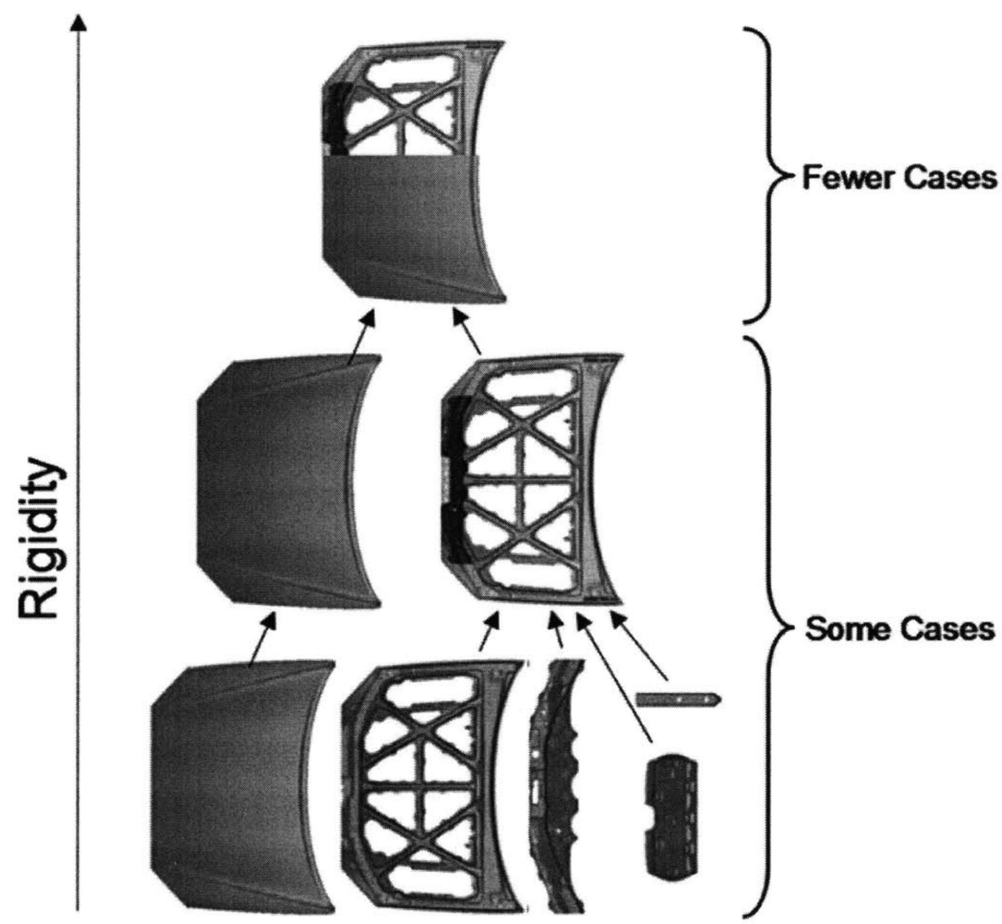
Figure 18: Functional Build Implementation Framework



The key point of Figure 18 is that the functional build strategy has limits in how it can be applied. In addition to the concept of rigidity, the concept of complexity is introduced. Complexity in this context increases, because KC chains become larger as components are built into subassemblies. Also, KC chains become more interconnected as subassemblies are built into the final assembly. Therefore, the likelihood of a functional build option decreases at higher levels of the vehicle assembly structure. At the vehicle level, gaps can be viewed as a series of butt joints between rigid parts. In this sense, the vehicle level build is essentially a nominal approach. Including a nominal approach in a functional build model may appear counterintuitive at first. However, the functional build model here could be viewed as a hybrid approach. Essentially, functional build increases the number of options one can consider to address dimensional issues. Of the options available with a functional build approach, the typical option available in a nominal build (reworking dies) is certainly an option that is also included in functional build.

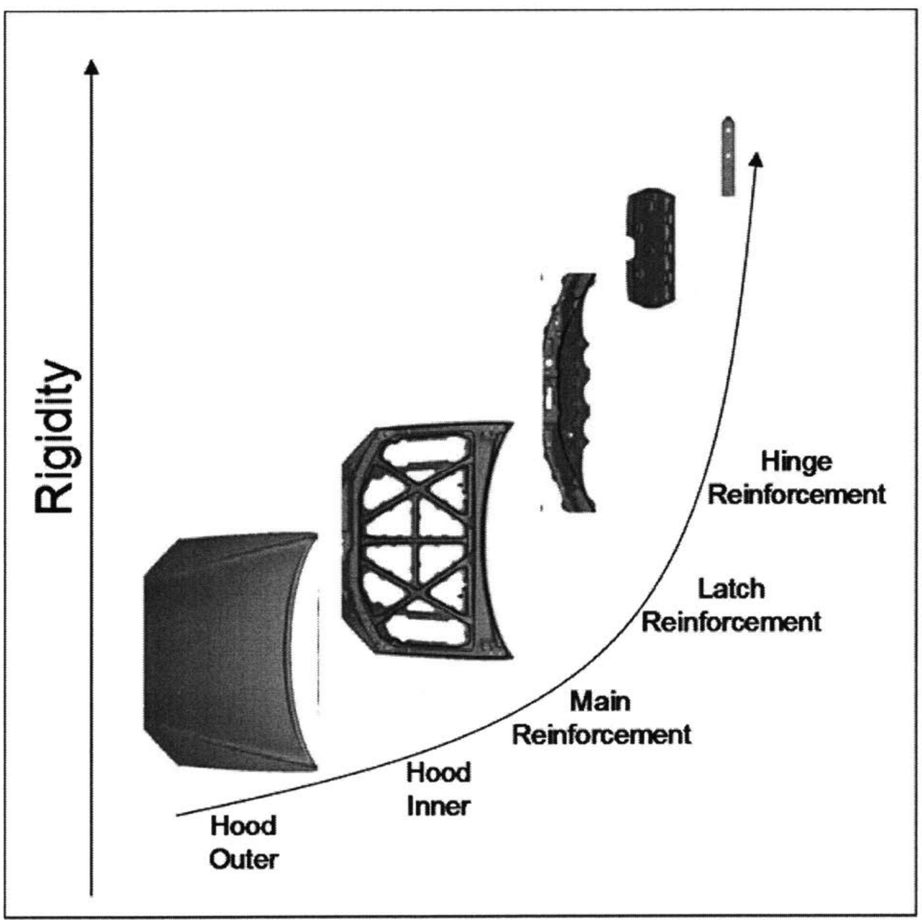
The model is valid for subassemblies that contain all compliant parts or a mix of rigid and compliant components and is divided into three regions – *some cases*, *fewer cases*, and *not likely*. What follows is an example hood subassembly that will aid in visualizing application of the model. The hood assembly process is shown in Figure 19.[35]

Figure 19: Sample Hood Subassembly



The actual assembly sequence could vary from Figure 19, but the sequence shown is sufficient for this example. At the lowest level are the components, which include the hood outer, hood inner, and three reinforcements. Individual components are stamped, and then the reinforcements are welded to the hood inner. At the second level of the assembly, the hood outer is still not attached to other components. The final operation marries the hood outer to the inner in a hemming operation, where the edges of the hood are essentially wrapped around the edges of the hood inner/reinforcements subassembly. At each level, the rigidity content increases and the number of parts contributing the KC also increases. This does not mean that rigidity of individual parts (shown in Figure 20), such as the hood outer, increases. The intent of the model is to show that the average rigidity at each subassembly level increases. This is a direct result of structural shapes formed by joining parts.

Figure 20: Relative Rigidity of Hood Components



To understand how the model applies to this example, let's examine the region in Figure 19 labeled *some cases*. This is the lowest level, where all four functional build scenarios (robust design, non-rigid parts, efficient solution, and luck) are a possibility. It is in the region of the assembly structure that in *some cases*, options other than reworking dies should be considered to address dimensional issues. In this stage of the assembly process, consider the case where one edge of the main reinforcement extends in the cross-car direction beyond its tolerance band by 0.5 mm. In the *robust design* scenario, sufficient clearance on the hood inner will allow the edge of the main reinforcement to be welded without impacting any Key Characteristics. Similarly, if clearances were not designed in the hood inner, perhaps the portion of the hood inner that would have interfered is also unexpectedly extended by the same or greater amount. This is the *luck* scenario, and since neither scenario impacts a KC, the deviation(s) from the print would be accepted. Had an interference existed that prevented assembly or impacted a KC, the *efficient solution* would require one of the two dies to be reworked.

At the second level of the assembly structure, consider the case where excessive die spring back has caused the hood outer to exceed the cross-car tolerance band by 0.5 mm. The *non-rigid* scenario applies very well here. If the hood inner/reinforcements subassembly is close to nominal, the hood outer may conform through the assembly process, eliminating the need to rework the hood outer die. Perhaps an even greater influence on the final dimension is the assembly process, as Guzman and Hammett showed in one door assembly study.[36] Regardless of how "good" the hood inner panel is, fixturing, clamping, welding, and hemming may contribute more to the final assembly dimensions than a component deviation.

Moving up the assembly structure to the subassembly level, *fewer cases* here provide opportunity for a functional build solution to a print deviation. The main reason is that the hood subassembly is now quite rigid. Therefore, the assembly process is less likely to cause "good" deformation, and the risk in waiting to find out rather than reworking a die is high. Nonetheless, the hood is not totally rigid and may deform during assembly, and correction via assembly is possible. Luck is also still a possibility if for example, in the case of the 0.5 mm hood outer deviation, the mating fender is shifted in the same direction. Complexity has increases at this point in the assembly process. Other related KCs (like those shown in Figure 9) would have to be assessed in this scenario and would reduce the feasibility of accepting the hood and fender deviations. If a functional move to the fender were possible, this also opens up the *efficient solution* options.

The final region in the model is the vehicle level, where the hood is assembled to the front end of a vehicle body. Here, a functional move entails the ability to change the location and/or orientation of the subassembly. The hood is rigid and can only be moved; it can not be changed. This region is labeled *not likely* because of the extent to which both Key Characteristics conflict and the KC chains interconnect.

It is important to note that the model is a general guideline based on the research of Daniel E. Whitney at the Massachusetts Institute of Technology and the many researchers at the University of Michigan's Transportation Research Institute. The model is intended to synthesize the overall scope of functional build. Another use of the framework is to aid in making design decisions for implementing an exterior fitting fixture.

4.5 Chapter Summary

This chapter defined two types of build strategies, nominal and functional, and then proposed a functional build framework. The framework combined the concepts of rigidity and complexity, and linked the two concepts to a set of functional build scenarios, which include robust design, non-rigid parts, efficient solution, and luck. As an assembly is built up into subassemblies and eventually into the final vehicle, the model articulates which functional build options are most likely.

The functional build model considers both technical and organizational issues. From a technical standpoint, rigidity is a key theme. As the number of "bad" parts in a subassembly increases, the ability to assess the impact of functional decisions becomes more difficult. From an organizational standpoint, the more deviations that are accepted in an assembly, the more coordination is required. As complexity increases in the KC chains, further organizational coordination is needed. Also, feedback on the feasibility of some functional decisions is not possible early in the validation process. For all these technical and organizational reasons, an increased number of functional decisions, in general, increases risk.

Through this understanding of the functional build strategy and KC analysis, the author was better able to assess LaPerre's past initiatives and understand the purpose of current initiatives that included the new fitting fixture. Using the functional build framework from Chapter 4, the KC analysis from Chapter 3, and the product development process from Chapter 2 as background, Chapter 5 explores the new fitting fixture initiative and both Chapters 5 and 6 further elaborate on organizational factors of successfully improving perceived quality at LaPerre.

Chapter 5 – Change Initiative

Chapter 1 introduced the competitive pressures in today's automotive market. The trend is for consumers to expect superior perceived quality, which includes (among other vehicle characteristics) consistent and tight gaps and flushness between exterior subassemblies. Recognizing this, all vehicle manufacturers have launched several initiatives to increase perceived quality over the past few years. In general, the industry has improved the perceived quality of vehicles a great deal. An additional effort to continue improving perceived quality at LaPerre was to improve their manufacturing validation process through a series of build events to identify and solve quality issues. This chapter outlines a portion of the improvement initiatives at LaPerre.

5.1 Motivation for Change

As quality expectation, product variety, and cost pressures have increased for automakers, leadership at LaPerre has been on a mission to increase volume and quality of engineering output with the same (if not fewer) resources. The common theme when automakers needed to improve over the past 25 years has been to study Japanese firms to benchmark and copy their "best practices".[37] The difficulty with this is that information is imperfect, and it is often difficult to quickly and fully understand and replicate the systems that make companies like Toyota so successful.

Rather than focus on other companies, LaPerre decided to benchmark their own internal divisions at each of their separate global regions. One high-ranking employee remarked, "We are studying who in our company are the best-of-the-best (BOB), copying whatever they do well, and implementing it worldwide." In their search to find the BOB in exterior fits, executives were fortunate to find a sister division that produced vehicles with gap and flush results that were far superior to the other divisions. As different LaPerre leaders visited and studied this division, the managers of the sister division repeatedly pointed to a fitting fixture when explaining their extraordinary ability to solve exterior fit issues during validation and production launch. For LaPerre, this became a focal point and tangible tool that could be copied and installed. Also, from a functional build standpoint, LaPerre leadership recognized that the functional build approach becomes a nominal build strategy at the subassembly and vehicle level (see Figure 18). The sister division's fitting fixture contained nominal control parts at the subassembly level, which further highlighted the nominal build strategy needed at higher subassembly levels.

5.2 The "New" Fixture

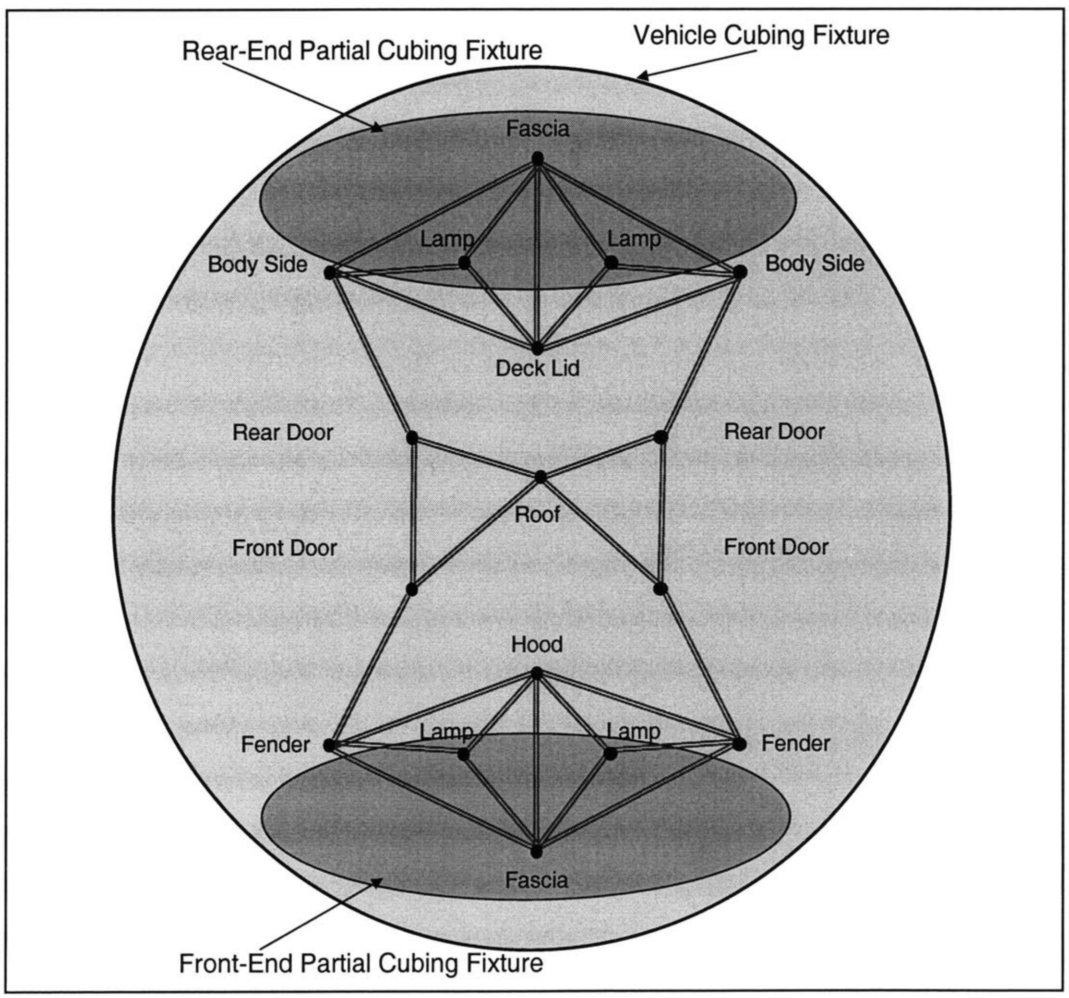
The tool at the sister division was a certain type of exterior fitting fixture. At the time, LaPerre used fitting fixtures for similar purposes. The main difference was the design of the fixture and how it was used.

On a typical LaPerre vehicle program, three exterior fitting fixtures were used. Using terminology from Chapter 3, LaPerre utilized two partial cubing fixtures and one full vehicle cubing fixture. The design of the partial cubing fixtures was similar to the one depicted in Figure 13 – one for the front and one for the rear of the vehicle. The full vehicle cubing fixture LaPerre used was similar to the one shown in Figure 14, but contained no control parts (simulated nominal surfaces), with the exception of head lamp "plug" gauges and a small number of control parts on some vehicle programs.

The partial cubing fixtures and full vehicle fixture at LaPerre were designed and managed by a mixture of organizational groups, and although the same vehicle team needed to use both fixtures, they were housed in different complexes. While there are several good reasons to use multiple fixtures housed in different locations, this can pose several problems for vehicle manufacturers when dimensional issues overlap multiple fixtures. The first problem is the potential for conflict between two fixtures. This can lead engineers to take time debating over which fixture is correct. Having fixtures located at multiple sites can waste valuable time as well. When team members have to compare results on one fixture to the other, they have to travel to multiple sites. Compounding the problem is the difficulty in transporting parts between the two sites. At several vehicle manufacturing sites, engineers are not permitted to carry parts into or out of a company complex. The required procedure can involve an arduous process of filing the necessary shipping requests and then following the process. One engineer said, "It takes over a day of my time to make sure my parts don't get stuck somewhere at dock, on a truck, or lost."

The overall goal of a fitting fixture is to validate vehicle exterior Key Characteristics, and aid in the validation and trouble shooting process. The chain of KCs in a vehicle is an interrelated system, and the intent of a fitting fixture is to view the interdependencies as a total system. It is difficult to validate and troubleshoot the KC system when several fixtures, designed and maintained by separate groups, are housed in multiple locations. Figure 21 shows how existing fixtures relate to the exterior KCs of a relatively simple example vehicle.

Figure 21: Select Key Characteristics Mapped to LaPerre's Existing Fixtures



The motivation for multiple fixtures at LaPerre is historical and primarily based on how they are organized. The engineering organization is divided into teams responsible for vehicle subsystems. The subsystem grouping aligns with how a typical vehicle assembly plant is organized. The three main sections of a plant are the body shop, paint shop, and general assembly. The body shop is where metal stampings are welded together to make a body-in-white (BIW). The BIW includes all of the sheet metal that makes up the body structure and exterior closure parts (door, hood, deck lid, roof, etc.). It is called a BIW before it goes to the paint shop. After the body is painted, the vehicle goes to General Assembly (GA) to get everything else (interior, chassis, lamps, fascias, exterior mouldings, glass, etc.) installed. As a result, engineering teams are grouped into the BIW team and the GA team. In the past, it was not entirely clear who owned the KCs on the vehicle, because the ownership of designing and manufacturing the parts was separate. Single ownership of the KCs could only be found at executive levels of LaPerre's organization. To their credit, LaPerre recognized this as an area for continuous improvement and assigned owners to all KCs in engineering and manufacturing.

After learning of these organizational divisions that are common among automotive companies, it is not surprising that separate fixtures emerge from different teams and that the designs can be somewhat different. Until recently, the BIW cubing fixture at LaPerre did not include front and rear end subassemblies such as lamps and fascias. Recognizing the need to have a total vehicle approach was another step in the right direction to solving vehicle system issues. Multiple fixtures, however, still exist at many manufacturers, and the segregation of fixtures tends to focus attention on subsystems rather than the entire vehicle.

In contrast to LaPerre's fitting fixtures, the sister division utilized a single fixture. Also, a major difference was that it had a full set of control parts. That is, for each production part evaluated on the fixture, there was a corresponding control part representing a nominal surface. This tool had many inherent benefits over LaPerre's current fixture strategy.

From an organizational standpoint, a single engineering group owns the vehicle exterior KCs. Teams of component engineers do exist, but a single subsystems team has assumed responsibility and has the necessary influence to own all exterior KCs. In manufacturing, the same consolidated ownership and necessary influence also exists within a single manufacturing engineering group.

From a socio-technical standpoint, first and perhaps the most obvious benefit is that a single tool alleviates conflicts between two separate fixtures. Also, single ownership of exterior KCs allows one owner to champion the use of the fitting fixture. LaPerre's sister division strongly emphasized that the fitting fixture was "the single master" tool on which to base decision and follow-up root cause investigation. Another advantage that the sister division repeatedly cited was the team-building nature of the tool. To them, the full vehicle fixture was more than just an engineering tool; it was a symbol of what everyone was striving toward, a vehicle exterior with "perfect" gap and flush dimensions. It was the focal point and central location where formal and informal meetings took place. Whenever there was a dimensional challenge to be solved, the team rallied around the fixture to attack the problem from a vehicle perspective. The sister division continued to emphasize how important it is to guide the focus of the team in the same direction.

One aspect of the fixture that facilitated team processes was the use of control parts. While this adds to the total cost of the fixture, it is a wise investment for the sister division. The control parts take dimensional issues from the abstract (measurement data) to the real (what the customer will see) and allows the entire vehicle team, including engineers, manufacturing representatives, and suppliers to visually evaluate, discuss, and quickly target follow up investigation.

5.3 Case Study

The value of instant and visual feedback throughout the validation and vehicle launch process were best described with examples reported by employees familiar with

LaPerre's sister division. The following is a typical scenario during the manufacturing validation stage of vehicle development (shown in Figure 3) on a vehicle program at LaPerre's sister division.

As the first completed vehicles were coming off the assembly line, an engineer noticed that a head lamp was not fitting correctly. The head lamp installer followed the correct process, but the lamp appeared to be misaligned relative to the hood. The root cause of the issue could have been related to a problem with the lamp's subassembly, lamp placement, hood subassembly, or hood placement. All four possibilities would point further problem solving in very different directions. To illustrate the high number of potential root causes, Figure 22 shows the four potential primary root cause paths, as well as select sub-path examples.

Figure 22: Potential Root Causes of Bad Lamp-to-Hood Gap

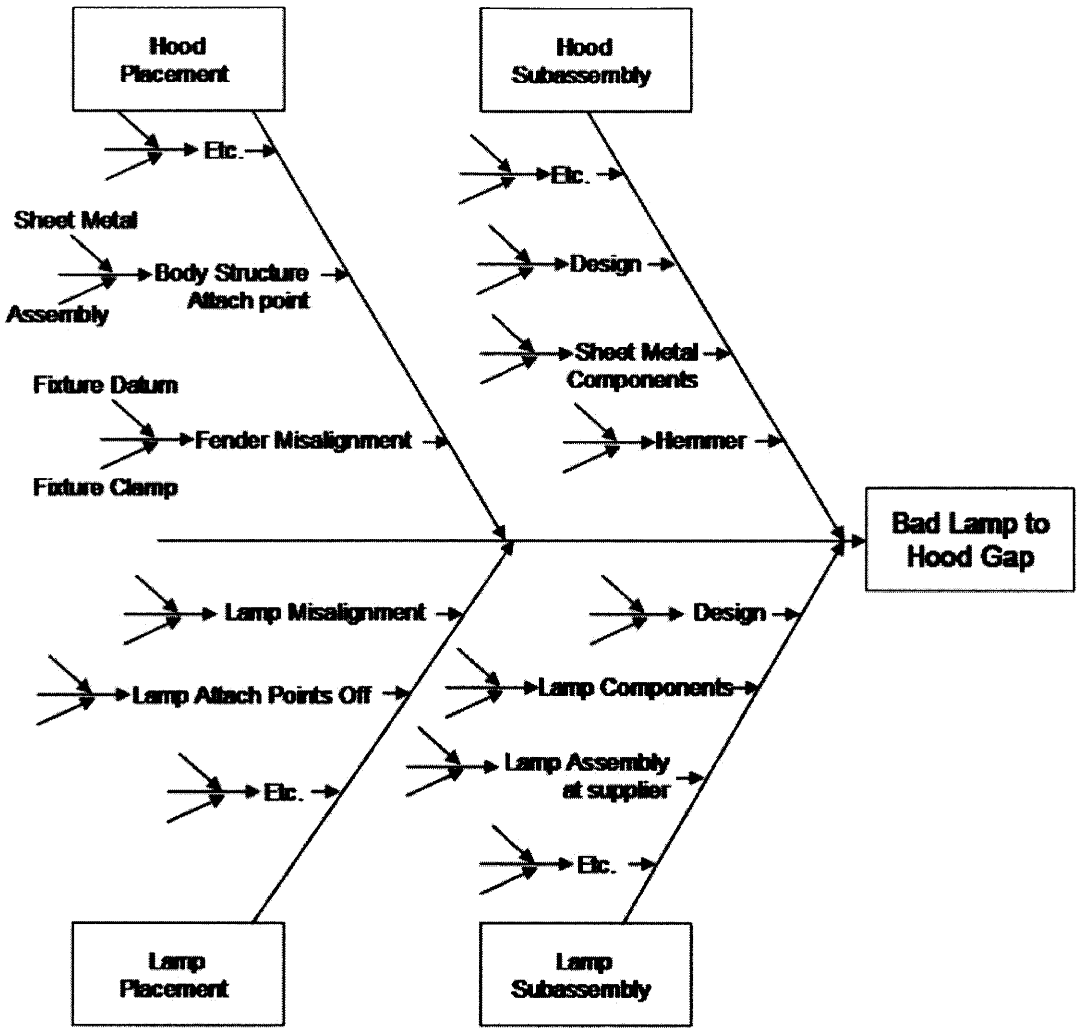


Figure 22 is simplified and incomplete, but still illustrates a sample of potential root causes and shows how the number of potential issues can be daunting. To aid in this problem solving process the fitting fixture at LaPerre's sister division can quickly eliminate 50% to 75% of the possible paths. Here is how it works. The fitting fixture initially has a complete set of control parts. Installing the suspect production lamp and comparing it to adjacent surfaces quickly rules out the "Lamp Subassembly" path on Figure 22, assuming the lamp-to-control gaps meet specifications. With the same logic, reinstalling the lamp control and installing the suspect hood subassembly can rule out the

"Hood Subassembly" path. Only two possible paths remain. Further confirmation of the root cause path can be found by placing the lamp control part on a production vehicle body. Essentially, the fitting fixture with control parts can quickly determine if the issue is related to the placement process or the subassembly. Additionally, if the problem lies in one of the two subassemblies, the fixture immediately shows which subassembly is "bad", ruling out 75% of the possible root causes.

At manufacturers that do not have a visual tool to quickly diagnose and gain consensus on the potential root cause, similar situations play out much differently. First, because there are multiple fixtures in multiple locations used by different groups, team members tend to trust their own fixtures. For example, a lamp supplier once used the partial cubing fixture and measuring equipment to confirm that the lamp dimensions were correct. The BIW engineers verified that the hood and body structure dimensions were correct. After inspecting parts on separate fixtures and carefully taking measurement data, which can take several hours to over a day of time,[38] both shared their data and could not agree on a potential root cause path. As problems like this persist closer to the start of regular production, the risk of slowing or delaying production increases.

5.4 Financial Impact Estimate

The total cost of a month delay of production start has been estimated to take an irrecoverable 2% of total vehicle lifecycle revenues.[39] While that might not seem like a high number, another way to look at the cost of launch delays is on a per vehicle basis. Assume that the average profit for a new vehicle (which is less likely to require hefty incentives) is $2,000. At an annual capacity of 240,000, each day of production that is delayed cost the manufacturer approximately $200,000 in profit alone.[40] Even if this estimate for profit is on the high side, the revenue loss has significant impact on manufacturers because their costs are largely fixed. This impact will only get worse over time if consumers continue to grow tired of new models in shorter and shorter timeframes. The key takeaway is that a moderate investment in a tool that can save even a short amount of time during a vehicle launch will easily pay for itself.

5.5 Initial Implementation Challenges

At first glance when the author was assigned to lead the implementation, it seemed like a straight forward task. All that was needed was to learn about LaPerre's current fitting tools, study the sister division's fixture, develop the business case, select a pilot vehicle program, and sell the idea. After a few weeks at LaPerre, it was clear that the project would be more challenging than anticipated, because the change impacted a large group of people. At any large vehicle manufacturer, changes of this magnitude require extensive communication to multiple groups to align upstream and downstream processes. A great deal of work is needed to ensure others understand the continuous improvement efforts. Once people can internalize and understand the initiative, only then are the building blocks in place for the organization to support the initiative.

It was clear that selling or pushing the fixture concept back on the organization would not be successful. Jan Klein from the Massachusetts Institute of Technology often discusses the idea of "pulling" change.[41] The concept suggests that it is necessary to first step back and recognize the gap between the current view of a problem and its true root cause. For example, one common and over simplistic explanation for quality issues in the automotive industry is that metal stampings do not meet specifications. A small progressive group of people at LaPerre has rejected this assumption as the sole barrier to improving quality. They stepped out of their environment by studying the sister division and have recognized a systemic and organizationally-based area for improvement rooted in KC ownership, problem solving tools, and an exterior part tune-in processes that have potential for increased discipline. The key to this change initiative is to get the rest of the organization to see this alternative explanation. Once this happens, the organization becomes willing to consider solutions and even take an active role if the issue is both important and urgent.[42]

5.6 The "System" Behind the Tool

This research shows that copying a tool or "best practice" alone is rarely enough to realize expected benefits in large complex organizations such as vehicle manufacturers.

The goal of this section is to articulate what those few at LaPerre intuitively understood. It begins by setting the organizational context at LaPerre, and follows with a strategic evaluation of the fixture implementation at LaPerre.

Throughout the 1980s and 1990s manufacturers pursued several new management trends with limited success. The disappointing results from the "shotgun blast" of buzzwords and three letter acronyms such as TQM (total-quality management), JIT (just in time), QFD (quality function deployment), and CIM (computer integrated manufacturing)[43] has made the working-level of many organizations numb to new initiatives.

Much literature has been written to explain why strategic initiatives fall short of expectations so often. In Michael Porter's 1996 article in the Harvard Business Review, he cites an example from the airline industry[44] that depicts strategy as a series of interrelated decisions, capabilities, and organizational culture. Porter cites Southwest Airlines as an example of good strategy that contains activities and practices that reinforce one another.

Southwest Airlines was one of the most successful airlines in 1996 and remains so in 2005. They focus on low-cost and convenient services on the routes they serve.[45] Southwest does not use the "hub-and-spoke" strategy of its competitors. It focuses on point-to-point short-haul trips, has no assigned seats, does not serve meals, does not have first class, and uses less congested smaller airports with cheaper gate fees.[46] Another decision that supports their low-cost position is to fly a single kind of aircraft – Boeing 737s. Having the same type of plane reduces maintenance costs and delays from breakdowns. The list of activities and decisions at Southwest are numerous, and Porter shows that almost all activities in the system reinforce the notions of low cost, frequent departures, and limited passenger services.

In contrast, Continental Airlines is organized around the hub and spoke model between major airports. They appeal to passengers who prefer meals during their trips, which are typically longer than those Southwest offers. First class amenities and meals are also offered, and because of the variety of flight distances, Continental's fleet has a mix of different planes.

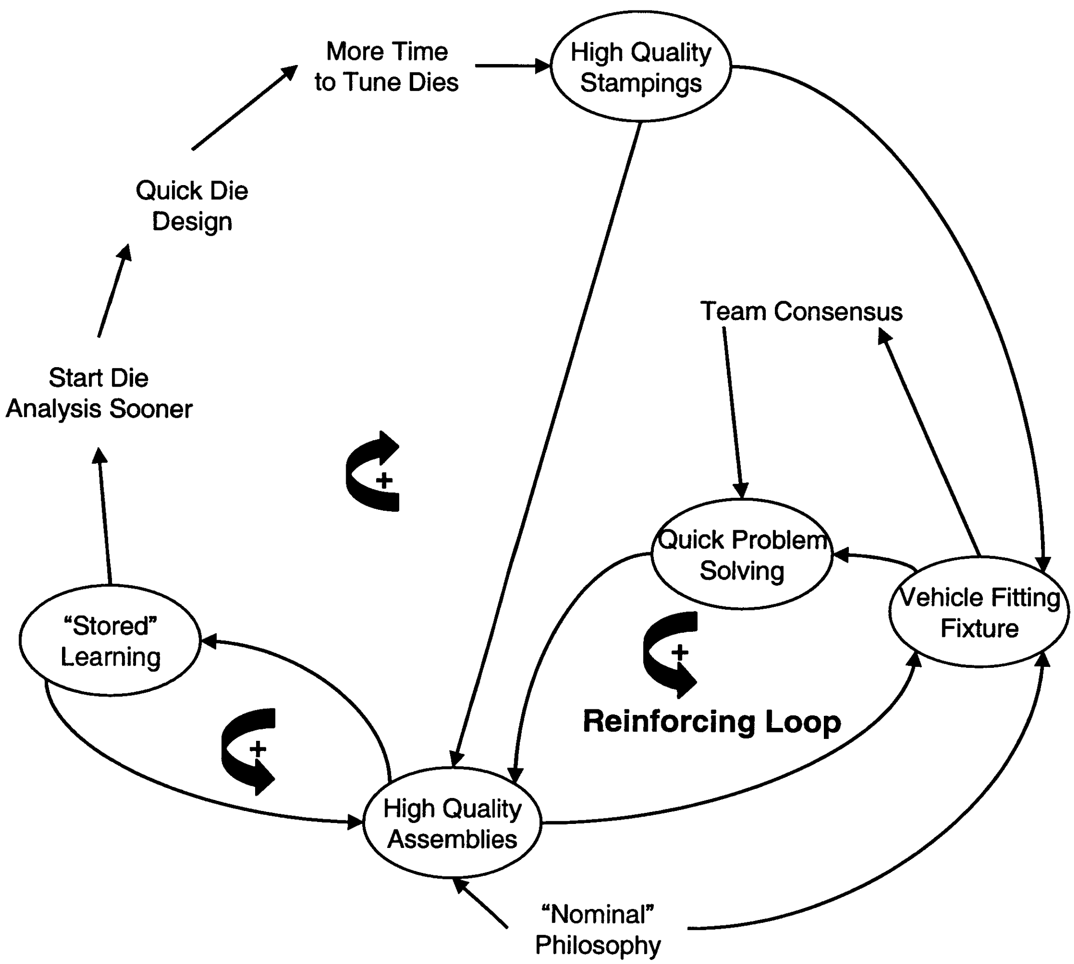
To respond to Southwest's threat as a competitor, Continental Lite[47] service was created, in addition to Continental's regular service. Similar to Southwest, Continental Lite flights were a low-fare point-to-point service without first class and meals. Continental Lite appeared to be a viable competitor for Southwest. There were, however, several differences between Southwest's and Continental Lite's operations. The existing fleet at Continental was comprised of a variety of planes, which caused higher maintenance costs and more delays compared to those at Southwest. Their systems were also designed to assign seats to customers, which increased costs and time required to board the plane. Finally, their operations were based out of major airports that are more congested, prone to landing and takeoff delays, and with higher gate fees than the secondary airports Southwest used.

In the end, Continental lost hundreds of millions of dollars, the CEO lost his job, and the Lite division folded,[48] because organizational constraints prevented them from effectively copying the entire Southwest system. This is a high-level example of how difficult it can be for an organization to implement a strategy made up of several reinforcing activities. The automotive industry is no different. In a study of why so many U.S. automakers had difficulty emulating the "best practices" of Japanese companies, Japanese and U.S. executives frequently cited the narrow focus of the learning efforts and the incentive to "cherry-pick" a single approach in hopes of a silver bullet solution.[49]

At LaPerre, implementing the new fitting fixture was especially susceptible to the "cherry-pick" phenomenon. It is a single tool that seems simple to purchase and start using. As the complexities and practices of the sister division unfolded, however, it became clear their performance was a result of more than a fixture. If LaPerre ignored the rest of the system, the new fitting fixture would end up just like Continental Lite.

A select group of leaders at LaPerre understands this, and they are implementing a host of cross-functional initiatives in parallel with the new exterior fitting fixture. Figure 23 is the author's attempt to model an ideal system that uses a vehicle fitting fixture and is based on numerous discussions and research of academic literature. It would be difficult to capture the complete recipe of success of any company in a brief academic-based project, but the model does highlight key activities that should be considered going forward at LaPerre Motor.

Figure 23: Vehicle Fitting Fixture System



On the surface, all of the activities and causes/effects in Figure 23 seem like common sense and indeed can be found in a plethora of public literature. It seems obvious that auto manufacturers want to produce high quality assemblies, retain learnings for continuous improvement, and solve problems quickly. Several more enablers at the sister division exist (e.g., consistent designs, die stamping technology, etc.) and for simplicity are not depicted in Figure 23. The enablers depicted in Figure 23 show that, similar to the Southwest example, this strategy is more than a collection of independent activities; it is a collection of *reinforcing* activities that enable and build on each other. Often times, these reinforcing activities are hard to understand, even by the companies that execute the strategy. For example, Intel knows that its processes for setting up semiconductor fabs are very effective. They recognize and admit they do not fully understand the system. As a result, a "copy exactly" policy is strictly enforced.[50]

An example of reinforcing activities in Figure 23 is the inner-most loop extending from *vehicle fitting fixture* to *quick problem solving* to *high quality assemblies.* The vehicle fitting fixture enables quick problem solving when issues arise, which in turn results in higher quality assemblies (as defined by KCs). As the vehicle's quality increases, the perceived value of the fitting fixture rises, and more individuals use it for problem solving. An added benefit is that, while the cycle reinforces itself, it also generates momentum in other parts of the system. Consider the same three-step cycle. As the perceived value of the fitting fixture increases, more people rally around it, which fosters team consensus in solving problems related to KCs. Greater perceived value of the fixture combined with team consensus further increases the likelihood of solving problems.

Circled elements of the model are central "nodes" on which the reinforcing loops depend. These warrant special attention, because without them much of the system falls apart. Organizational structure is not shown in Figure 23. This element is critical to successfully execute many of the activities representing nodes, and the topic is discussed in Chapter 6. The primary nodes are *quick problem solving, "stored" learning, high quality assemblies, high quality stampings, and vehicle fitting fixture.*

Quick problem solving is at the root of how the vehicle fitting fixture is used. The fixture merely points engineers in the right root-cause direction as discussed earlier in this chapter and shown in the root-cause diagram (Figure 22). Without the ability to quickly respond to and solve problems that are discovered with the fitting fixture, the benefits are lost.

"Stored" learning is also critical to the success of the system, and includes both personnel expertise as well as electronic tools that capture learnings and help to avoid making the same mistake repeatedly. Like most companies, LaPerre has made efforts to capture learnings. Applicable lessons learned are often difficult to find within large organizations. LaPerre leadership recognizes this, and improvements to learning systems are currently under development to help better organize and capture learnings. The sister division has been capturing stamping die learnings electronically also for some time now. A structural advantage that the sister division has is that the variety of vehicles produced is relatively small, and they typically share a similar architecture. In a smaller vehicle manufacturing organization, it is easier for engineers to deeply specialize and improve part and tool designs after each program. In conjunction with consistent architecture are the sister division's long-term relationships with suppliers that have consistently produced the same parts from model to model. This expertise among suppliers also lends itself to effective continuous improvement.

In contrast to the consistency at the sister division, most automotive manufacturers have the challenge of launching many different types of vehicles on architectures that vary greatly from vehicle to vehicle. This is one aspect of the system that LaPerre simply does not have the ability to recreate, and therefore is not able to "copy exactly". Can the system still work without this enabler? Is there some other activity that the larger manufacturers can add into the system to compensate? These are the relevant questions that should be considered as manufacturers implement changes such as the new fitting fixture at LaPerre.

Perhaps the strategy will work fine without this element. At the very least, however, those who oppose the new fixture initiative may point to this in an effort to hinder the implementation. Therefore, in order to successfully respond to these challenges, it is essential that implementation leaders give careful thought to all the elements of the strategy.

High quality assemblies (i.e., ones that successfully deliver KCs) are to some extent both a goal and an enabler. This poses an interesting "chicken or the egg" question. In order to gain full utilization of the vehicle fitting fixture, the assemblies have to first meet a minimum level of quality. The reason for this is that production parts must first fit on the fixture, and then be close enough to nominal that they do not collide with adjacent control parts. This means that subassemblies supplied to vehicle manufactures must meet a certain minimum level of quality in order to gain the benefit of a vehicle fitting fixture. Another input to this element of the system is **high quality stampings**. Even if a manufacturer uses the functional build approach, stampings must meet a minimum level of conformance to specifications in order to build assemblies that will fit on the vehicle cubing fixture. Also, although the functional build discussion in Chapter 4 minimized the influence of components on subassemblies, the level of quality of stampings has some impact on the quality of assemblies. The takeaway from these two elements of the system is that the vehicle fitting fixture must be consistent with build philosophy. A minimum level of quality, which all automotive companies have struggled to define and attain, is needed for stampings. An even higher level of quality is required for subassemblies.

The **vehicle fitting fixture** is the diagnostic tool that enables quick diagnosis of problems. It also facilitates team consensus by providing a central location to assess the dimensional status of a vehicle. By providing a central location and tool, teams can agree that a problem exists and quickly move toward finding the root cause (see Section 5.3).

5.7 Engineering Processes – Alignment with Build Strategy

In order to gain the benefits of the sister division's vehicle fitting fixture, the dimensional strategy must align with the fixture design. A large portion of the investment in the new fitting fixture is in the control parts. The control parts provide numerous benefits such as the ability to evaluate how individual subassemblies impact KCs before all of the adjacent production parts are ready. This decoupling of subassembly activities shortens the critical path[51] of manufacturing validation, and allows evaluation of assemblies as soon as they become available. While the control parts hold great potential for these kinds of improvements, the build strategy must yield parts that can be physically installed on the fixture.

To understand how build strategy impacts whether a production part will fit between surrounding control parts, consider the functional build framework in Figure 18. The highest subassembly level (*fewer cases* region) is where the majority of fitting fixture parts falls. According to the build model, potential for a functional solution to a problem is fairly low at the subassembly level. To an extent, a "functional" approach to larger subassemblies is very close to net or nominal build.

This point is worth reiterating. Under the functional build model presented in this thesis, manufacturers should strive to produce subassemblies (e.g., doors, deck lids, lamps, fascias, etc.) that are within engineering specifications. LaPerre's sister division is very clear about this. In fact, to emphasize this, they don't even use "functional build" in their terminology. Of course, it is unrealistic at any automaker to expect 100% of points on subassemblies to meet what engineers predicted in a specification, and there are a small number of decisions made for subassemblies that fit the definition of functional.

The word functional has different meaning for different people. Most functional build literature cites the complexity of educating the workforce at large automakers. One manager in an assembly plant remarked, "Functional decisions are what you do when you don't know the root cause." Another high level engineering executive told his definition, "Design and build parts, and then throw out the prints." To his credit, he followed his comment with, "When we learned this from the Japanese companies, I think we misinterpreted them." Indeed, misunderstanding of functional build is prevalent. Perhaps this is why the sister division avoids the term completely. LaPerre has also recently shifted their terminology, in conjunction with the vehicle fitting fixture implementation, to increase discipline and focus teams on nominal targets for subassemblies.

At the component level on the functional build framework in Figure 18 (*some cases* region), the functional build decisions are related to the *high quality stampings* node on Figure 23. What qualifies as high quality in this system? It almost certainly depends on the situation at hand. Only those skilled in the art of functional build can answer that question when presented with a specification deviation and one of the four functional build scenario options from Table 1. What can be observed is that both a minimum level of stamping and subassembly quality is required to even consider accepting a specification deviation. If a part or subassembly is out of specification by 4.0 mm, a die will clearly have to be reworked. As deviations get closer to 0.75 or .25 mm, it is hard to say for sure if a die rework will be needed or if a functional solution is possible. Whatever the cutoff is, the maximum acceptable deviation is likely to shrink as the market demands increasingly stringent gap and flush dimensions.

5.8 Chapter Summary

This chapter began with the motivation for the change initiative – to increase vehicle perceived quality. To do this, LaPerre studied other divisions and learned, among other things, about a vehicle fitting fixture. This fixture is different from LaPerre's in that it is used at the sister division for verification and trouble shooting of the entire vehicle exterior. Also, the fixture contains a full set of control parts. A case study was presented to show how this fixture can quickly eliminate a significant portion of the potential causes of dimensional issues. The fixture enables quicker evaluation of issues, but reducing the number of issues and properly responding to them takes more than simply purchasing the new tool.

A system was proposed that supports quick problem solving, "stored" learning, and high quality assemblies and stampings. The system is more than a collection of activities. It is a set of activities, inputs, and outputs that reinforce one another. This system is ultimately what will impact perceived quality at LaPerre – not just the fixture itself. Perhaps even more important than the system itself is the organizational foundation that supports it. The organization's role in gaining the benefit of the fitting fixture system is the topic of Chapter 6.

Chapter 6 – Organizational Considerations

Chapter 5 highlighted the many interrelated activities that contribute to the success of the vehicle fitting fixture system. Underlying this system is an organizational structure that supports many of the activities needed to make the system work. This chapter dives deeper into the organizational issues that are important for LaPerre to consider as they attempt to implement the new fitting fixture. To help the reader gain an understanding of how LaPerre's organizational processes influence the change initiative, an overview is provided, and the change is then discussed in terms of its overall strategic fit with the current organization.

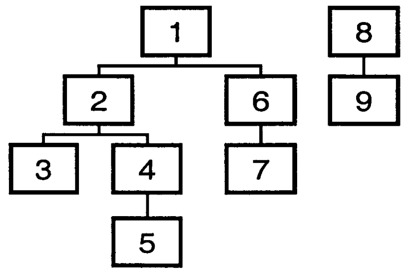
6.1 Organizational Overview

It is helpful to have an understanding of the organizations involved with the fixture implementation. Table 2 shows what the author views as the LaPerre groups that are impacted most. The Table 2 legend shows how the groups listed are related to one another. The intent is to show how groups interact with one another, and in some cases the reporting structure is consistent with these interactions.

Table 2: LaPerre Organizational Overview

Legend: Organizational Grouping

Group 1
.Group 2
..Group 3
..Group 4
...Group 5
.Group 6
..Group 7
Group 8
.Group 9



Group	Description
Manufacturing & Engineering Integration (MEI)	Integrates Manufacturing and product engineering activities Lead for manufacturing engineering strategic initiatives Director of MEI is executive champion of fitting fixture initiatives
.Change Agents	Provide support for fixture implementation and manage pre-production organization that will use fixture
..Author	Temporarily assigned to lead fixture implementation
.MEI Group Managers	Responsible for group of MEI engineers that are assigned to similar vehicles
..Pre-Production Group	Supports screw-body build and utilizes fitting fixture before it is sent to the assembly plant
Body-in-White (BIW)	Installs all equipment in plants for new vehicles
.Fixture Group	Manages design and construction of fitting fixture
Stamping Division (SD)	Internal supplier that produces sheet metal components
Suppliers	Supply exterior parts (lamps, fascia, etc.)

Manufacturing Plant	Utilizes fitting fixture during launch and for continuous improvement throughout vehicle lifecycle
.General Assembly (GA)	Installs parts on painted body
.Body Shop	Assembles/welds metal stamping components into body structure with unpainted closures
UAW Skilled Trades	Union labor that conducts screw-body assembly and loads/unloads fitting fixture parts at the pre-production facility and the assembly plant
Launch Organization	Owns manufacturing budget for all new vehicles and staffs temporary teams in plants to support vehicle launch
Component Engineering	Engineers responsible for design of individual components and divided by functional area
.Body	Designs and releases vehicle bodies
.Trim	Designs and releases other (typically non-metal) exterior parts such as lamps, fascias, glass, etc.
Vehicle Team	Management leadership team assigned to and directly responsible for a vehicle's engineering and production launch
.Vehicle Team Manger	Leader of vehicle team
.Vehicle Team Launch Manager	Leads manufacturing launch activities
..Lead Engineers for Subsystems	Leads all component engineers for vehicle or group of similar vehicles
...Component Design Engineers	Component engineers reporting to Lead Engineer for Subsystem
..Dimensional Engineering Team Manager	Leads product engineering dimensional activities
..Dimensional Launch Team Manager	Leads manufacturing engineering dimensional activities

The following is a brief description of how each group is involved with or impacted by the fitting fixture initiative:

- **Manufacturing & Engineering Integration (MEI)** is the group that, because of their strategic manufacturing planning activities, has embarked on the fitting fixture implementation. This group provides the necessary implementation resources to carry the implementation forward. Also critical is the group director's ability to influence corporate leadership and his peers. While some of the fixture ownership lies within MEI, the commitment of several other groups is needed. The MEI director's influence and that of his change agents has been instrumental in gaining involvement from other groups.
- **Body-in-White** encompasses the engineers that manage all measurement equipment and fixtures. The lead engineer for the pilot program, with the support of his direct management, has been critical to gaining "bottom-up" momentum for the implementation. Going forward, the lead engineer assigned to each vehicle will continue to be heavily involved with the definition of the fixture and will tailor it to meet the unique needs of each vehicle model. To ensure the various stakeholders are involved with the fixture early in the vehicle development process, this person must be comfortable reaching out to and networking with all groups listed in Table 2.
- The **Stamping Division** produces all of the metal components for vehicles, and is described in more detail in section 6.2.
- **Manufacturing Plants** will house and utilize the exterior fitting fixture from the early launch phase through the end of the vehicle's life. The two key groups that will benefit from the fixture are Body and General Assembly (GA). In the past, each had their own fixture, which made troubleshooting complex in some cases. Now a single fixture is utilized, and the two groups will benefit from having a single focal point when problems occur. This gathering point will be in the measurement room within the body shop, because of the extensive measurement tools available there.
- The **Skilled Trades** group assembles parts on the fitting fixture and is described in more detail in section 6.2.
- The **Launch Organization** manages the manufacturing budget for new vehicles, and their support is key to ensuring that the fitting fixture is funded for each program.
- The **Vehicle Team** is responsible for engineering and launching a new vehicle. They lead the component and launch engineers. Within the vehicle team are the subsystem

leaders and the Dimensional Engineering and Launch team mangers. These are the people who together manage the vehicle at the system level. It is no surprise that they also see the benefits of a fitting fixture, and are instrumental in generating awareness of the fitting fixture to their teams. Additionally, the chain of command of the vehicle team goes up to the highest-ranking executive in product development that ultimately approves funding for the fitting fixture.

6.2 Strategic Lens

In viewing the fixture implementation through the strategic lens, this section will examine factors such as organizational groups, job design, and incentives. First, characteristics of the sister division's organization are introduced and related to parts of the fitting fixture system from Figure 23. A comparison to LaPerre will then shed light on organizational changes that may be needed to make the fitting fixture system work. Finally, the formal structure and goals of LaPerre's groups will help to identify alignment or disconnect between the current organization and what is needed for a successful and sustainable implementation of the fitting fixture.

6.2.1 The Organization Underlying the Fixture System

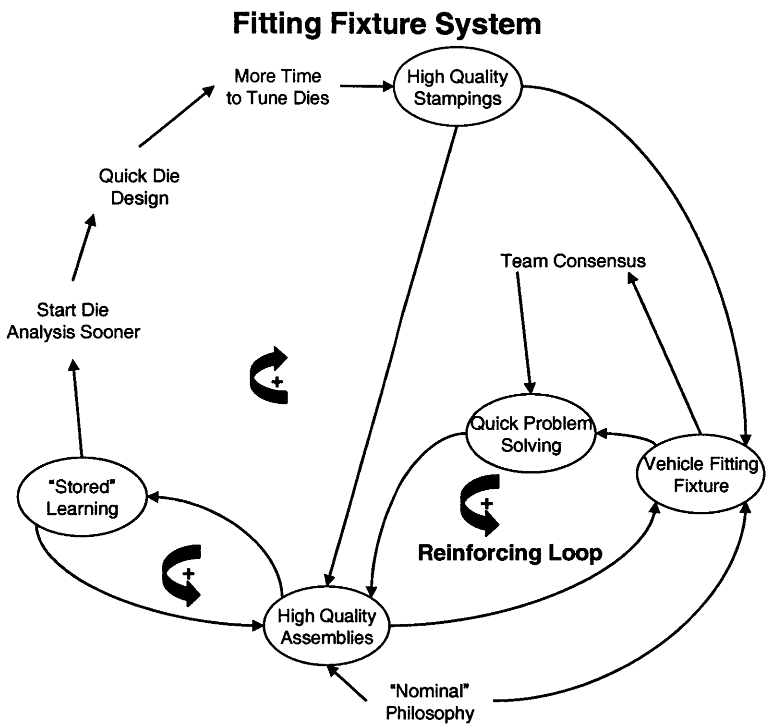
The sister division's organization is designed to support two of the key nodes in the fitting fixture system – quick problem solving and "stored" learning. Without effective problem solving, the vehicle fitting fixture merely diagnoses issues that do not get addressed. Stored learning is also a key enabler to producing high quality stampings and assemblies (as shown in Figure 23), which is a requirement to mount production parts on the fitting fixture for evaluation.

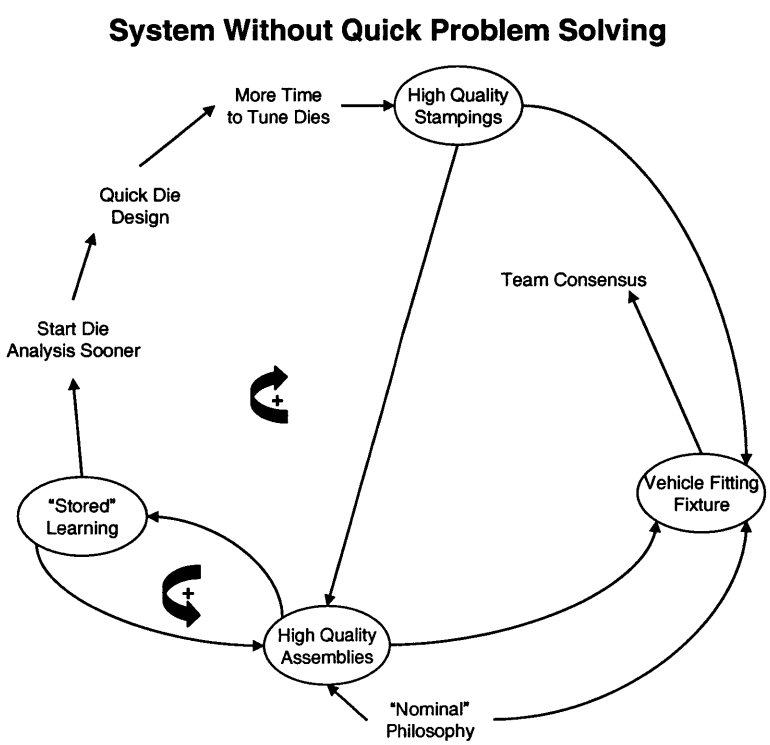
At the sister division, a factor that significantly contributes to quick problem solving is centralized ownership of vehicle KCs. In product engineering, a single group owns the KCs on the vehicle exterior. In manufacturing engineering, a single group is responsible for execution of the entire vehicle exterior dimensions.

At LaPerre, the component engineering group is organized by subsystems, which divides design ownership of the vehicle exterior into multiple sections. In the past, single ownership of KCs that cross subsystems could only by found at high levels of the engineering hierarchy. Part interfaces were managed through product development meetings and other forms of communication. Similar to the organization of component engineering, LaPerre's manufacturing organization has also lacked a single owner for all exterior KCs in the past. Recognizing this, one manufacturing engineering organization at LaPerre is in the process of reorganizing in a way that allows ownership of all vehicle exterior fits in a single group, and product engineers are also assigned to specific KCs.

Figure 24 illustrates the impact to the fitting fixture system if organizational structure prevents quick problem solving. The link from the fitting fixture to high quality assemblies – the only direct output from the fixture – is taken away. In reality, the fitting fixture may still provide some benefit even if problem solving is not "quick". The model clearly shows, however, that the benefit of the fitting fixture is limited or constrained by a company's ability to quickly address issues that are identified with the fitting fixture.

Figure 24: System Impact without Quick Problem Solving





The other key node in the fitting fixture system that is strongly tied to organizational processes is "stored" learning. The sister division's career and supplier management practices support learning through stability. Management in manufacturing engineering, for example, has changed very little in the past several years. Likewise, as the same engineers and suppliers have worked on the same part, model after model, lessons learned have contributed to tacit knowledge. At LaPerre, some functions have developed technical experts, but not to the extent of the sister division. Management (for often good reasons) has also been fluid at LaPerre. From a supplier management standpoint, LaPerre also does not have the stability of the sister division.

The impact of taking "stored" learnings out of the fitting fixture system is difficult to determine. If "stored" learnings were the sole contributor to high quality stampings and assemblies, then the lack of these three elements would collapse the entire system. Other factors surely contribute to high quality stampings and assemblies. What can be said, however, is that stamping/assembly quality are reduced as "stored" learnings diminish.

6.2.2 Process and Incentive Alignment

Corporate Alignment

The goal of the fitting fixture initiative, to increase vehicle exterior perceived quality, is highly aligned with the overall corporate goal to increase excitement for LaPerre's cars and trucks. The link between this corporate goal and the change initiative is very strong. Each month, top company leadership meets with the leader of the group responsible for the implementation, Manufacturing and Engineering Integration (MEI). In addition to high-level attention, the overall goals of the MEI group are also highly aligned with the fixture implementation.

The Source of the Inititative

The MEI group is made up mostly of manager and senior-manager employees. Some are individual contributors that focus on strategic initiatives, and others have teams of people that support the integration of manufacturing with production engineering on specific vehicle programs. The vehicle fitting fixture implementation team was initially made up of a few highly influential members including the director of MEI, with an additional member from Dimensional Engineering (DE).

Traditionally, MEI had responsibility for vehicle bodies. Recognizing the need to integrate activities for the entire vehicle, MEI recently acquired responsibility and resources for GA parts also (lamps, fascias, glass, etc.). This formal responsibility for the entire vehicle aligns well with the use of a vehicle fitting fixture that combines both body and GA assemblies.

Although the new activities and resources are consistent with the fixture implementation, the fact that it is a new process has proved to be one of the challenges of the change initiative. While the fixture is being designed in the prototype and early production stages of vehicle development, unexpected engineering changes must be communicated to the fixture designers through the MEI group. When a body subassembly is expected to change, linking mechanisms are in place to notify the MEI group when the change is first being considered. For GA parts, when a change is considered, it is critical for component engineers to work with the MEI group also. In the past, this link has not been strong, and MEI often learns of GA part changes later in the process. With a vehicle fitting fixture, late change notification will increase costs, because it is much easier to make changes to the fixture design before machining is started. Therefore, formal and informal communication is required between GA engineers and MEI.

Through several interviews and group workshops, a process was developed to identify how this new activity will take place on the pilot vehicle fitting fixture implementation. The framework used was to define high-level activities and then outline what is involved in each step. For each step, inputs and outputs were identified. Also included were owners, methods, and metrics.

The Stamping Division and Skilled Trades

The Stamping Division (SD) is LaPerre's internal supplier of most of the sheet metal components (by weight) for vehicles. SD is also responsible for engineering, producing, and tuning in dies for the component parts. As an integral member of the team evaluating vehicle Key Characteristics, SD is very involved with evaluating parts on the vehicle fitting fixture and determining if die rework is needed.

Two major metrics by which SD is measured are utilization and part delivery. While quality is emphasized, it is common for automotive stamping suppliers to place a higher priority on timing schedules for part delivery. The complexity of the functional build concept has also led to multiple interpretations of functional build. Some automotive manufacturers have found this issue to cause a decline in quality discipline during earlier phases of the development cycle. While quality is eventually improved before vehicles are sold, fixing problems late in the process is costly. For this reason, LaPerre and SD are working to increase understanding of the improved build strategy and refine quality and timing metrics.

The other metric that, to some extent, can work against the fitting fixture system is stamping supplier utilization. Stamping suppliers' goals to decrease costs give them incentives to increase utilization, which in part, has led them to design batch-change processes when die rework is necessary. In order to gain the benefits of an exterior fitting fixture, quick problem solving must be followed by quick action. If die rework is required to solve a problem, the build team needs a quick response in order to evaluate their decision, and waiting for the next batch change at a stamping supplier may be too late. High-level attention to the pilot implementation will likely cause incentives for SD to respond to die rework requests quickly. The real challenge for SD and any other large stamping supplier will be to organize in a highly responsive manner for multiple vehicle programs while keeping costs low.

Some hindrances at automotive stamping suppliers are work rules and job design requirements of the unionized skilled trades workforce that builds the dies. Because of union contract requirements, the workforce is fairly rigid, unlike Toyota where staffing is so flexible that die makers move to and from partner die shops outside of Toyota.[52] Workforce rigidity is also a challenge from an implementation standpoint. Ideally a "train the trainer" approach would be utilized, where skilled trades workers for the first assembly plant receive training at LaPerre's pre-production facility. When the fixture is shipped to the plant, the trades workers would then go to the same plant and train their peers. This requires both mobility and a long-term commitment on the part of skilled trades employees. Given that the union allows incentives for little more than seniority, finding trades workers with their own internal motivation to make such a commitment will be a challenge for LaPerre as it would be for all unionized (United Auto Workers) manufacturers.

Chapter 7 – Conclusions & Recommendations

This chapter provides a summary of findings and conclusions for this thesis. It is organized into the two categories proposed in the hypothesis: engineering *and* organizational processes needed for a successful fitting fixture implementation. Also provided are recommendations for LaPerre going forward. While these recommendations are based on sound technical and managerial theory, it is important to note that they present a formidable challenge to put into practice.

7.1 Engineering Processes

One goal of this thesis was to lay out engineering processes and technical principles that 1) motivated the fitting fixture implementation and 2) are necessary to gain the benefits of a new fitting fixture. Gap and flush Key Characteristics were highlighted as characteristics that are important to customers and often times difficult to achieve in a vehicle system due to KC conflicts. The existing fitting fixtures at LaPerre attempt to aid in KC validation and trouble shooting, but the current system of three separate fixtures for the vehicle is sub-optimal. A new total vehicle fixture was proposed, based on learnings from a sister division, to combine the three fixtures and add full control part capability to the design. The intent of the new fixture is to foster discipline and team-based trouble shooting of KC issues from when the first production parts are available through the stable production phase of a vehicle lifecycle.

A build framework was proposed that is consistent with the use of the new fixture. The general attributes of the build model are:

1. As rigidity increases, the number of potential function options tends to decrease, making die rework more likely.
2. As subassemblies progress through the process, they become more complex, increasing the risk of functional decisions.
3. As KC expectations continue to increase, the ability to make functional decisions decreases.

Fortunately, as gap and flush requirements become more stringent, die technology is improving. With technological advances such as computer automated machining, formability analysis tools, and virtual die surface templates, the first time quality of stampings increases.

In light of the observations and analysis presented in this thesis, the author recommends the following for LaPerre:

1. Aggressively pursue die stamping technology improvements. This is becoming a "cost of doing business" in the automotive industry, and to keep up with increasingly tight gap and flush requirements, the initial quality of metal stamped components must continually improve.

2. Continue efforts to identify the sister division's activities that are related to the vehicle fitting fixture. Much progress has been made, but understanding the "system behind the tool" is as important to LaPerre as it was to Continental Lite.

3. Adapt current product change tracking systems to proactively identify potential changes to the vehicle fitting fixture. This also has a secondary benefit. Not only does the communication of potential late product changes lower fixture costs, it also has the potential to drive the much-needed communication between manufacturing and product engineering groups.

4. Explore the possibility of documenting KCs and managing them explicitly within the engineering organization that releases designs. This would record both KCs and the interfaces that impact KCs. As the vehicle changes throughout the development process, this document has the potential to clarify the impact of changes on KCs, to facilitate communication, and to assist in coordinating tradeoffs.

7.2 Organizational Processes

Equally important to successful implementation of a new fitting fixture at an automotive manufacturer are organizational considerations. First, the change initiative must be carefully orchestrated so that stakeholders take a personal interest in the implementation. This can be achieved through a high-level executive commitment and a grass-roots effort. Now that the implementation is successfully under way for the pilot program, the author recommends the following for LaPerre going forward:

1. Like many corporations, the overall perception of change initiatives at LaPerre is one of apathy. For this reason, changes need to come both from the top executive down and from the lowest-level line worker upward. People must see the urgency for change, recognize their personal interest in the initiative, and then become owners of the change themselves. "Generating pull" is a necessity to achieving sustainable change.[53]

2. Develop human resources to align with build philosophies (as defined by Figure 18). The skills and capabilities of an effective build team is unique and includes the following:
    a. A strong and influential leader that has broad experience in body shop tools, stamping dies, screw body builds, dimensional management, and engineering.
    b. Seasoned team members that are experts in single parts or subsystems.
    c. Partner suppliers with seasoned engineers that are experts in their parts or subsystems.

   This unique mix requires manufacturers to create two different types of career paths and to foster stable relationships with suppliers that have similar human resource development policies. LaPerre must develop generalists (across processes and parts) and also develop technical experts that can recognize trends from one vehicle to the next. The sister division was very clear in the benefits of developing experts and partnering with suppliers over the long term.

3. Examine the learning systems in place at LaPerre's sister division. Because the sister division has fewer and more consistent vehicles, they have mastered the art of capturing and applying lessons learned from one vehicle program to the next. The luxury of vehicle consistency has provided an ideal environment for them to develop this system and is an excellent starting point for LaPerre to build from and adapt to their vehicle development process.

4. To support the fitting fixture implementation (and several other product development processes), LaPerre should continue to foster communication between manufacturing and product engineering. This will support the management of KCs as they progress from upstream engineering phases to downstream manufacturing processes.

Appendix A: Acronym Definitions

GA – general assembly

BIW – body-in-white

MVB-NS – manufacturing validation build non-saleable

MEI – Manufacturing and Engineering Integration

SD – Stamping Division

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