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# DIVERGENCE IN PLATFORM COMMONALITY: EXAMINATION OF POTENTIAL COST IMPLICATIONS

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## 1. Introduction

Platforming has become an important means of cost-sharing across industrial products. Example include Volkswagen's A platform (including VW Jetta, Audi TT, and Seat Toledo), the Joint Strike Fighter program (variants for the Air Force, Marines, and Navy), and Black and Decker's electric hand tools. Among many benefits, platforming enables cost savings - utilizing a platform enables firms to spread fixed cost investments in manufacturing equipment, and boost unit volumes, enabling learning curve benefits and variable cost savings.

Recent work by Boas (2008) has shown that products built sequentially often exhibit divergence from the platform. That is to say, commonality decreases during the design phase of the product, resulting in lower commonality than originally intended. This divergence is driven by an imbalance of current over future interests in the platform. Boas identifies both beneficial and detrimental effects of this behavior.

We discuss some of the findings from case studies of divergence, and their implications for the management of design. Further, we examine in detail one potential detrimental effect – cost growth.

Boas [2008] determined that only 1 of 7 organizations studied had a consistent measure of commonality – the JSF program. This program provides the only data available as a starting point for studying the possibility of a connection between divergence and cost. Namely, one of the variants suffered airframe commonality decreases from 40% to 19% from 2002 to 2005, and increased its budget for development by $10.4 billion over that same period, on $44.8 billion total cost at 2005 [GAO 2005].

Cost growth is a significant problem. Example abound, from the Apollo Moon program's 64% growth [CBO 2004] to Boston's Big Dig's 420% [Glen 2006]. This phenomena is present in many industries involving large projects, in addition to construction and aerospace mentioned above, transportation [Flyvbjerg 2004], software development, energy, and defense. Cost growth has been multiply attributed to technical difficulties, scope growth [CBO 2004], poor initial cost estimation, cost-plus contract incentives, rework, and schedule delays. Many of these problems are linked by feedback – for example, schedule delay on projects with high labor-fractions imply cost growth, as the project is unable to unload its fixed labor costs while waiting for the offending subsystem or group to complete its work. Traditional systems engineering wisdom suggests that the "iron triangle" of cost-schedule-performance cannot be fully controlled – guidance is given that one of the three variables can be defined, one can be actively managed, and one will float freely despite the manager's best efforts.

Divergence is intimately intertwined with these feedback loops. Plans for commonality contain assumptions that are critically affected by divergence. Directly, increased unique parts and processes leads to cost growth via increased unit costs, decreasing economies of scale, and reduction of learning effects. Indirectly, the performance shortfalls surfaced at common interfaces require redesigns, rework, and schedule extensions. To date, the impact of divergence on cost growth has not been studied, nor has been divergence been well measured.

The general objective of this paper is to discuss the feasibility of measuring divergence within a project, with a view to improving cost forecasts.

Measuring the state of commonality is potentially complex – we could measure shared parts, shared production facilities, or shared operational processes. Section 4 includes a detailed discussion of potential commonality metrics, but we advance the following important principle now: we are interested in commonality that drives cost savings, therefore we should identify a metric of commonality that can be tied tangibly to cost.

## 2. Review of Past Work on Platform Divergence

To date, we have conducted 10 case studies on the phenomenon of divergence[Boas 2008, Rhodes 2010]. Seven of the studies were conducted in industry, three in government. These studies span a range of industries, listed below. The three government case studies were all low-volume, high cost systems, although not on the order of Case Study F.

**Table 1. Industrial Case Studies**

| |
|---|
| A: Automotive |
| B: Military Aircraft |
| C: Commercial Aircraft |
| D: Business Aircraft |
| E: Printing Presses |
| F: Comm. Satellites |
| G: Semiconductor Mfg. Equip. |

For example, Boas (2008) describes a divergence in an automobile manufacturer's truck platform. Significant savings were expected relative to the separate development costs – reduction in lifetime headcount for the project of 20% and significant direct manufacturing cost savings. The platform was developed concurrently with the SUV, followed by truck development 2 years later. Despite the existence of platform manager and the fact that truck production was expected to double SUV production, many platform design decisions were more heavily weighted towards the SUV. Truck development had not yet been initiated when these decisions were made, with the consequence that the SUV had greater resources and design fidelity with which to influence the platform design. Boas (2008) highlights the platform's braking system as a tangible example of divergence. Higher performance brakes were designed for the platform to meet the greater braking needs of the heavier SUV. The truck team evaluated the platform brakes relative to a modification of previous truck brakes, finding the truck brakes lighter and cheaper for their vehicle. The decision to drop the platform brakes from the truck eliminated the variable cost savings gains from economies of scale, changing the combined cost of the truck and SUV lines.

Several common themes emerged from these 10 case studies on divergence. Studying commonality decisions reveals that there are a number of subtleties and common behvaiors exhibited by many platforms, suggesting that what looks common at a high level is difficult to deliver as more detailed views are examined.

Lifecycle offsets are common in platform development – the design of products participating on the platform rarely occur simultaneously. These offsets create an upfront development penalty while offsetting benefits to future systems and decreasing total potential benefits. Further, offsets cause future systems to be uncertain, making commonality difficult to evaluate and increasing the likelihood of divergence.

Divergence can be separated into two types – beneficial and detrimental. Beneficial divergence incorporates information acquired during the design process, which improves the overall program, either by reducing overall cost or enabling other program goals. Detrimental divergence does not produce an overall benefit, although it may well provide benefit to an individual product.

Boas (2008) and Rhodes (2010) highlight acceptable factors leading to beneficial divergence. Namely, market conditions change, necessitating a re-evaluation of the platform strategy, technology changes during the design process, or design activities reveal flawed assumptions about similarity between intended common systems. Unacceptable factors are also highlight, including poor management of commonality, intentional pursuit of uniquenesss, and failure to consider lifecycle benefits in design decisions.

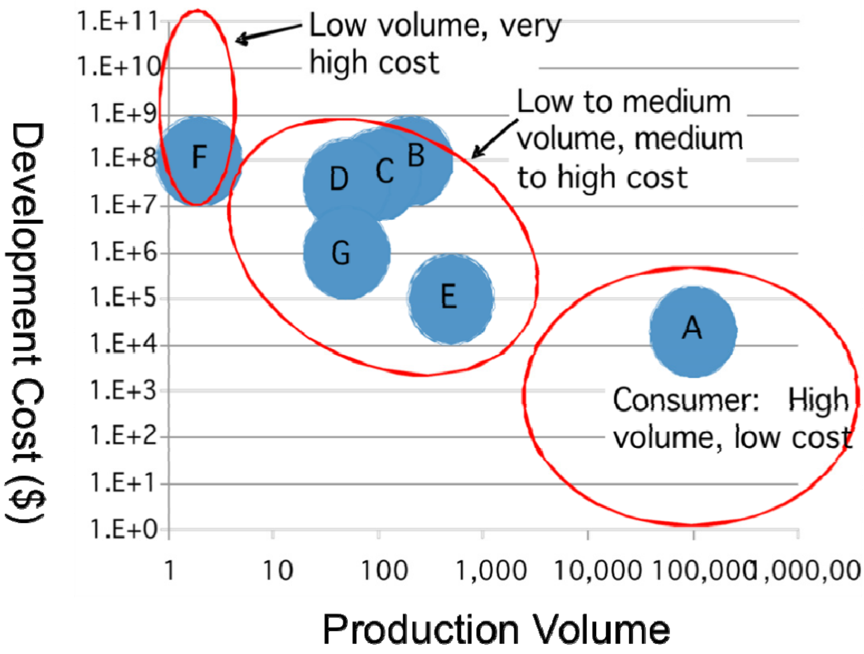


**Figure 1. A depiction of the breadth covered by the industrial case studies**

## 3. Implications for Commonality Management in the Design Process

The discussion of commonality and the divergence phenomenon suggests that effort is required to maintain commonality, and further, that upfront commonality decisions should be made with care.

The dominance of individual products over platforms in many corporate structures necessitates a 'commonality owner' at the platform level [Boas 2008]. This owner must have sufficient design and cost oversight of the platform to ensure that product design decisions reflect the platform's purpose. Further, this owner should exist for the entire lifecycle of the platform, not simply the design phase of the first variant. Additionally, commonality decisions should be reflected in the product development process.

Commonality should be pursued as a means to an end, not as an end unto itself. Mandating commonality levels in the design process can obscure opportunities for beneficial divergence. Therefore, while we feel it is important to monitor commonality through design reviews and in project management, the highest level at which commonality is tracked needs to have sufficient scope to view commonality changes in light of the overall system benefit.

Platform planning can benefit significantly from more detailed examination of the feasibility of commonality. The further into the design cycle the variants participating in the platform, the more accurate the set commonality level. The greater the lifecycle offset, the more the focus should shift to component reuse for the latter variant, and the greater the need for the first variant to be able to absorb the investments made during its design cycle, without support from production volumes of latter variants.

We now examine one aspect of commonality management in detail – the cost implications of divergence.

# 4. Cost Implications of Divergence

We have shown that divergence is a potential disruptor of product platform strategies. In addition to broad management guidance presented above, we examine potential measures of divergence and cost which would enable a product design manager to actively track the impact of divergence.

**Measuring Commonality**

Measuring the state of commonality is not a simple proposition, but is necessary for establishing a predictive model. Different views of the system suggest a variety of definitions for commonality.

An inventory view suggests commonality should be defined by the number of parts shared. However, when common parts are modified to become unique parts, the extent of the modifications varies from minor to significant. This suggests that an inventory view would give a lower bound on commonality. Thevenot and Simpson (2006) review a number of different commonality indices based on common parts counts. These parts differ based on whether they explicit consider a hierarchy of parts (as in a Bill of Materials), whether they assume there is an 'ideal' level of commonality, and whether the index is weighted by parts count or cost of parts.

From a manufacturing cost perspective, similar parts (intended common parts with small modifications for different products) do not necessarily forecast significant cost growth. If similar parts require minor manufacturing changes, are built from the same raw materials and sourced from the same supply chains. Analysis of the manufacturing process, capital equipment use, and sourcing could yield a more accurate assessment of the state of commonality and its impact on manufacturing cost. Park and Simpson (2005) provide a detailed breakdown of production costs, and also list 6 different levels of 'sharing' across platforms in production, ranging from partial feature sharing to facility sharing.

Enlarging the field of view still further, we might have the following lenses – interface control field, integration and test, and lifecycle views.

Counting stable interfaces can yield an important view of the state of commonality. If the similar part continues to share the same interfaces as the intended common part, the impact on the system will be lower. Parts which interface with the external environment may survive changes with their internal interfaces intact – however parts with only internal interfaces are unlikely to change without any modification of their interfaces (why would they be changed if there was no impact on the rest of the system?). The greater the change at the interface, the greater the change propagation through the system. For example, if a chassis and suspension are intended common, but then the suspension is modified to support heavier vehicle weight, there is a chance that the chassis will need to be modified to accommodate greater loads at the chassis-suspension interface. Thevenot and Simpson (2006) reference a proposed a commonality metric that explicitly incorporates common connections as part of a Percent Commonality Index (PCI).

Integration and test procedures reveal important knowledge about the state of commonality. Classically, integration reveals unknown rework – mating supposedly common parts inherited reveals uncommunicated design changes. In this fashion, integration represents an important step towards determining final system costs, in that it reveals more about the state of commonality. However, integration is not a cause of divergence, nor does the design of integration procedures offer information about state of commonality. This perspective suggests that it is important to consider the timing of the measurements made, rather than offering a strong candidate measurement.

Building on the views expressed so far, a lifecycle perspective adds the operations phase of product life. Plans for commonality could include common support infrastructure, shared replacement repositories for common parts, etc. While it may be tempting to exclude operations given that costs are largely locked-in, operations often represent a dominant fraction of product revenues and costs, as such, small shifts in the commonality plan reveal significant costs.

Finally, we have the organizational and process views, grounded in the people that actually execute the program. It is important to capture this dimension, because duplicated staff assignments will drive costs despite common systems. While this situation may seem illogical in a parallel development process, it is has been shown to arise frequently in sequential platform development. Human processes have more opportunities to specialize around products rather than across the platform, whereas parts and manufacturing have much tighter change controls. Whether or not this specialization is beneficial depends on the transition time and costs. Common parts / systems owners compared to relevant headcounts at the product level could yield insight into the state of commonality.

Finally, accounting figures on shared costs could yield a perspective on commonality. While costs are an advantageous measure, in that they are often the most important project metric and translate readily towards our goal of measuring cost growth, they also pose several challenges. Namely, common parts / systems are not necessarily tracked in separate cost centers, as opposed to being absorbed by the first product, and costs can be subjectively allocated to suit missed targets.

The above discussion is based on the idea that measuring the state of commonality is equivalent to measuring divergence. Clearly divergence is only evidenced in time-series of commonality. However, there is one other important difference. While commonality is comparable across different platforms, divergence measured as the change from the original commonality goal is predicated on the level of detail invested in the setting of the commonality goal. Divergence of 10% on one program could be very difference from 50% on another, if one commonality goal was set 2 years into the program while the other was set at the first executive briefing where the idea was brainstormed. Therefore, caution needs to be exercised when comparing divergence measures on different programs, and renormalizations used as appropriate.

Based on the above discussion, we recommend the following commonality metrics:

- common parts as a fraction of total parts
- common project metric as fraction of total project metric (ex. weight)
- common manufacturing processes / time
- fraction of testing activities shared
- fraction of operations processes shared

The emphasis here is on generating simple time series which are accessible in the organization. Several of the cases we have studied historically have attempted to implment commonality measures. The more complex the measure, the more difficult it will be to track. Our experience suggests that maintaining a consistent measure is more important than tracking all facets of commonality savings.

**Cost Measures For Product Platforms**

Many platforms are initiated to capture cost-savings. The accounting of cost across a platform is not a simple task – platform investments have to be spread across products and time according to an apportioning scheme, and the resulting savings are realized in many different functions.

Any platform cost accounting system must span enough firm functions to include the hypothesized mechanisms by which platforming reduces costs. Notably, platforms enable economies of scale by boosting production number, thus enabling fixed costs to be spread more broadly. Further, these higher volumes enable learning curve benefits. A number of supporting costs reductions are also achieved, through lower inventory numbers and lower product support activities [Fixson 2004].

Past efforts have described methods for cost estimation and accounting. Park and Simpson (2005) used activity-based costing to develop a production cost estimation framework. They create a hierarchy of costs ranging from unit costs to facilities costs, into which common costs and unique costs can be slotted. Niazi (2006) describes several options for estimating and classifying production costs, but without specific reference to platforming. These approaches include reasoning from similar known cost cases, process-step based costing, parametric analysis of past program costs, allocated operation cost of machinery, and activity-based costing. No references have yet been found to describe how platform *development* costs have historically been allocated among products. Boas (2008])produced a preliminary cost model of commonality based on sharing fixed costs associated with common components, but did not place any historical costs in the framework, or suggest how the model could be used to estimate future costs.

Overall, we are interested in the topline cost which could upset the initial project economics associated with platforming. This has two implications. First, total cost of variants and platform (compared against the non-platform strategy cost estimate) and unit costs (including allocated platform costs) are the dominant numbers used in project economics, so these are the two cost categories we must obtain. Any cost breakdowns beyond this, be they into lifecycle phase, fixed vs. variable, recurring vs. non-recurring, are extra. Second, beyond these two measures of cost, we are by definition interested in the cost measures used by the project to create their case for platforms, as our hypothesis revolves around the soundness of the initial platform economics assumptions. Therefore, we recommend two measures of cost:

- Total cost, corrected for any changes in the number of units produced
- Total cost for each product, corrected for any changes in the number of units produced
- Average cost per unit for each product, computed as total cost divided by number of units produced

These measures of cost and divergence suggest that it is indeed possible to track the cost implications of divergence on an active program. While no evidence is available to directly support the hypothesis that divergence contributes to cost growth, we have highlighted a number of the mechanisms by which divergence disrupts initial cost predictions. These measures could be used to track the impact that divergence has on cost assumptions for a product platform, thus enabling product managers to manage divergence within the design process.

## 5. Conclusion

We have argued that divergence is a sufficiently important phenomena that it merits inclusion in the management of product platorms. Decreases in commonality have been observed in 10 case studies to date. This divergence can be managed by creating an owner of the platform, and by shifting commonality investment burdens towards early variants. Platforming is supported by a number of cost strategies, such as economies of scale and learning effects. Given the broad incidence of cost growth and the theoretical disruption of cost forecasts caused by divergence, it would seem prudent to introduce measures of cost and divergence that enable managers to identify cost implications before cost growth negates the benefits of platforming. Several measures of cost and divergence are reviewed, and a limited subset recommended for their ease of implementation.

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