Chapter 2
Crafting Platform Strategy Based on Anticipated Benefits and Costs

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Abstract In this chapter, we introduce the benefits and penalties of commonality (both to the customer and the manufacturer), emphasizing the need for anticipation of divergence when estimating benefits. We highlight the importance of mapping commonality strategy to the financial benefits, with a view to creating long-term competitive advantage for the firm.

2.1 Introduction

Platforming, the sharing of products or processes across products, has become an important means of cost-sharing across industrial products. Examples include Volkswagen's MQB platform (including VW Golf, Audi A3, and Seat Octavia) (Pander 2012), the Joint Strike Fighter program (variants for the Air Force, Marines, and Navy), and Black and Decker's electric hand tools (Meyer and Lehnerd 1997).

The use of platform over the last three decades has grown in response to market demand for variety. Consumers have come to expect $50, $100, and $150 version of a hand drill to choose from (Halman et al. 2003). Car buyers now enjoy bundled option packages (Basic, Leather, SportPlus), supported by option code sheets that could fill a book. This variety has a direct impact on the firm—for example, one automotive model can have as many as five million possible variants, when considering all of the offered options in combination (Cameron 2011). The process complexity deployed to support this market variety can threaten the organization's survival. A recent study of wasted complexity at Proctor and Gamble identified $3 billion in savings (Wilson and Perumal 2009).

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Platforming is a strategy for providing variety to the market against a reduced cost base. When executed well, it can provide a vital competitive advantage to the firm. Firms have cut costs by 30 % and reduced lead times by 50 % by employing commonality (Pander 2012). The ability to bring products to market quickly and cheap can create significant first mover advantage. However, gaining this competitive advantage is not quick or cheap. The list of firms that have attempted to build platforms and failed is long. Many firms fail to reach their commonality targets—the Joint Strike Fighter has famously seen divergence from 80–90 % parts commonality down to 30–40 % parts commonality (Boas et al. 2012). A senior executive in Automotive stated his belief that learning platforming takes at least two product lifecycles.

Sharing parts does not fundamentally create competitive advantage. Commonality as a strategy is only successful insofar as it enables financial advantages, be it increased revenue or decreased cost. In fact, we will show that platforming requires significant upfront risk, in the form of large multiproduct investments and downstream risk of low product differentiation—platforms can negatively affect the firm's brand.

We begin an examination of platform strategy by weighing the benefits and costs. We argue that the firm's ability to achieve a competitive advantage through platforming is rooted in a meaningful strategy process, examining the investment required against the downstream savings. In this chapter, we first provide a holistic overview of the benefits. Then we examine the associated drawbacks and costs. We review the data on divergence in commonality, to understand the potential downside risk. Finally, we illustrate how the choice of commonality strategy (what to make common) should be mapped to the desired benefits to be achieved.

2.2 Trade-Offs in Platforming

The discussion of platforming and commonality as a strategy is perhaps best illustrated in the context of trade-offs posed by this choice of strategy, as revealed in the literature. These trade-offs arise from conserved parameters and shared efforts—examining them provides a starting point for examining cost dynamics.

In platform development, there are a number of high-level trade-offs posed at the beginning of the platform development (Otto and Hölttä-Otto 2007). The trade-offs are critically related to the main architectural parameters, such as number of variants, range of performance, sequencing of variants, and degree of commonality. In turn, the decisions about these parameters are made about the expected markets for the variants, whose relevant characteristics here are performance requirements, willingness to pay, and availability/timeliness. The market "causes" the first set of trade-offs we explore.

2.2.1 Trade-Offs Caused by the Market

Firms create multiple variants for market reasons. Customers grouped by similar pricing and performance expectations can represent submarkets, which if served individually can represent greater overall profit than producing a product which serves their average expectation. Meyer and Lehnerd (1997) originally described a process for segmenting a market using a grid tool, illustrating a number of different strategies for spreading commonality investment across a range of product prices and market segments.

These market-facing tensions have been framed in the literature as a trade between variety and commonality. Ramdas (2003) segments the market implications of variety into four categories—the dimensions of variety, the product architecture, the degree of customization, and the timing of variety. In particular, research on understanding the costs of variety forms an important counterpoint in the tension between variety and commonality (MacDuffie et al. 1996; Martin et al. 1998; Du et al. 2001; Blecker and Abdelkafi 2006). Further, the trade between closed set discrete variety (e.g., along a linear dimension of variety such as horsepower) and the potential for mass customization has been a fruitful direction of research (Alptekinoglu and Corbett 2008; Blecker and Abdelkafi 2007; Jiao and Tseng 2000; Rungtusanatham and Salvador 2008). Research has begun to unpack the underlying mechanisms which create the variety—commonality trade-off—Rungtusanatham and Salvador (2008) note that difficulties identifying latent needs and differentiation opportunities within marketing activities can lead to static offerings.

Commonality strategies architected to deliver this variety in turn create the threat of cannibalization (Sanderson and Uzumeri 1995; Kim and Chhajed 2000), where customers with higher willingness to pay can meet their performance requirements by buying the lower-performance product. Sanderson and Uzumeri (1995) describe a case in the DRAM market, illustrating how sales trajectories can show both within-platform cannibalization and generation to generation platform cannibalization. Absent detailed customer data allowing the manufacturer to bucket variant sales by segment, cannibalization can be weakly inferred from sales trajectories and product introduction timing, but the quality of the inference varies. Variants that are closely spaced are easier to platform but are at greater risk of cannibalization. One mechanism of this cannibalization is that shared components in the lowest cost variant may be subject to quality standards as applied to higher performance variants. Ulrich et al. (1998) find "for low-quality segments, brand price-premium is significantly positively correlated with the quality of the lowest quality model in the product line" (Ramdas 2003). Viewed from the other perspective, Nelson et al. (2001) describe how overdesigning lower-level variants can place acquisition and maintenance costs above the reach of some customers, thus decreasing expected platform volume and profitability.

In addition to the threats to submarkets created by platforming, there is an overall brand threat. Cook (1997) notes, "ironically GM's market share relative to Ford only began to recede in the mid 1980s as GM's brands—Chevrolet, Pontiac, Oldsmobile, Buick, and Cadillac—became less distinctive through the use of common platforms and exterior stampings that reduced product differentiation" [reproduced from de Weck (2006)]. The concept of a trade-off between perceived product differentiation (and its effect on sales) and the benefits of platforming is a difficult one to measure, in that brand is influenced by many factors, and the signal from product differentiation is spread among the timings of the individual variant introductions.

The idea of flexibility of platforms is related, in that platforms can create opportunities for future variants, opportunities which are only revealed over time. The existence of a relevant platform can speed time to market, and also reduces development cost for the variant. There are existing tools for comparing flexibility's benefits against costs. Namely, Triantis (2000), Otto et al. (2003), Jiao et al. (2006), and Rhodes (2010) have framed commonality as a real option.

Baldwin and Clark (2000) argue that modularity has been a central driver of innovation and growth at an industry level, working from deep studies in the computer industry. It is important to note that this growth did not necessarily accrue to all firms—the final external trade-off that we note is a potential threat posed by competitors entering value-creating segments of the market on top of the firm's platform.

2.2.2 Internal Trade-Offs

Thus far, we have described the trade-offs with external influences. There are also a number of trade-offs that emerge through the development cycle. For example, firms often desire flat development budget profiles. If the concurrent development of the platform and all of its variants doesn't fit under this flat budget, a common technique is to phase variant development. Boas (2008) describes the trade-off created between phasing development and divergence from the platform exacerbated by the offset. Cusumano and Nobeoka (1998) describe a set of strategies for phasing development (ranging from parallel to sequential), highlighting how overlapping development phases, which he titles "rapid design transfer strategy," can strike a balance in this trade-off. Additionally, Cusumano and Nobeoka (1998) highlight how development head count time series represent a possible measurement of the phasing of development effort.

Insofar as platforms are large product development programs, they embody a whole host of constraints not specific to platforms. Personnel constraints create constraints for platforms, in that faster ramp up and ramp down times come at the expense of challenging training and quality. Existing manufacturing facilities constrain total capacity and inventory. Past capital equipment constrains current production methods as well as future capital availability (Rungtusanatham and Salvador 2008). These factors apply broadly to product development, so we do not explore in depth here—where appropriate, they are raised below in conjunction with specific platforming issues.

Work in the engineering literature has defined a variety of metrics, with a view to watching one of the key state variables, the actual level of commonality. In theory, each of the trade-offs should result in movement of an appropriately set commonality metric. For example, Thevenot and Simpson (2007) take manufacturing costs into account with a commonality metric where parts are weighted by cost, building on earlier work by Jiao and Tseng (2000).

We can sum up the internal trade-offs resulting from commonality in three key criteria for commonality (Cameron 2011). Commonality strategies must be grounded in technical feasibility—a concept of a design that can be expected to span a range of performance. Commonality strategies must be financially beneficial—commonality is a means to an end. Finally, commonality must be organizationally possible—shared designs and co-investments in future products must be supported by organizational structure and process.

2.3 Benefits of Commonality

Much has been written on the topic of platforming and commonality, primarily stemming from seminal work by Utterback and Meyer (1993) and Robertson and Ulrich (1998), although earlier work can be found from 20 years previous (Collier 1981). These early works cited a number of benefits, such as enabling future rapid product introduction, increase model introduction rate, decreased development cost, economies of scale in manufacturing, and faster introduction of new technology into existing product lines. Since the early work on platforming, a broad body of literature has grown up around the concept of platforming, but no consensus around the list of benefits has emerged, despite several past efforts to build a list of pros and cons—see Fisher et al. (1999).

To begin, we break the benefits of commonality into three categories: (1) Revenue Benefits, (2) Cost Savings, and (3) Risk Benefits. Figure 2.1 shows examples of the tangible benefits possible in each of these categories. We delve deeper into these benefits in the remainder of this chapter.

Embedded in the notion of benefits and penalties in the management literature is the idea that managers weigh these factors when making rational decisions. As compared to the more quantitative literature on commonality, the diversity of benefits in the management literature is broad by comparison and is most likely to discuss commonality decision-making as grounded in organizational structure. As a potential frame of reference, van Maanen's organizational decision-making separates decisions into rational strategic, political, and cultural. The rational strategic frame is dominant in the management literature. However, political decisions (the embodiment of organizational power or position) are also referenced, such as in Cusumano's (1998) discussion of heavyweight program managers. Cultural decision-making is referenced in passing, such as creating a culture of reuse, but

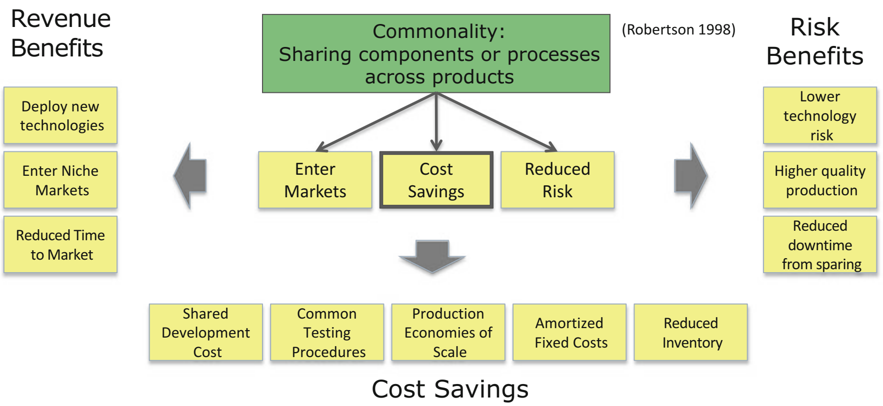

Fig. 2.1 Three benefits of commonality: (1) market benefits, (2) cost savings, and (3) risk benefits

has not been the subject of much descriptive work. We have found that decisions are dominantly framed under investments, as discussed in the following section.

Based on the cited literature and over 30 case studies on commonality (Wicht and Crawley 2012; Boas et al. 2012; Rhodes 2010; Cameron 2011), we have constructed a comprehensive list of commonality benefits (see Table 2.1). We have divided the benefits of commonality into five categories, roughly aligned in the order in which they occur. Cost Saving benefits are listed primarily under the phase of the product lifecycle in which they occur—Design, Manufacturing, Testing, and Operations. In addition to the traditional breakdown of a product lifecycle into Design, Manufacturing, Testing, and Operations, we have included Strategy Benefits, to explicitly recognize that some of the benefits relate more closely to Revenue Benefits and Risk Benefits than to Cost Savings.

It is important to note that not all of these benefits accrue to every platform. Additionally, we have explicitly separated reuse benefits from proactive commonality benefits. Reuse benefits in a sense exclude prior development work from the platform system boundary, in that future commonality was not intended (Unintended Commonality). Proactive commonality benefits, which comprise the majority of the table, include the initial investment and variants inside the Platform system boundary (Intentional Commonality).

The benefits of commonality from a product family planning perspective are primarily captured in the Strategy Phase. Recognizing that it is rare that the scope of product families (the platform extent, the number of variants, the performance/cost of each variant) is known entirely in advance, some of these benefits accrue due to the uncertainty in the planning phase. For example, the firm’s flexibility to enter niche markets once the platform has been defined represents an important strategic benefit (Pine 1993; Meyer and Lehnerd 1997). By contrast, within the originally forecast platform scope, platforms can help companies reduce their time to market (Clark and Fujimoto 1991; Meyer et al. 1997), as less overall design, test, and manufacturing work is required overall to bring several variants to market.

Table 2.1 List of commonality benefits (Note: the benefits are not causal or assured, but rather the potential to achieve the benefit has been shown to exist)

Phase	Benefit	Rationale	References
Strategy	Enable faster variant time to market	The common portion of the design has already been built, so only the unique portion has to be designed	Clark and Fujimoto (1991), Meyer et al. (1997)
	Enter niche markets	Designing unforecast variants on top of the common platform enables the firm to recognize and enter markets as they appear	Pine (1993) Meyer and Lehnerd (1997), Robertson and Ulrich (1998)
	Deploy new technologies	Time and cost to deploy technologies is reduced where interfaces to the platform are identical.	Meyer (1997), Jiao et al. (2007)
	Lower technology risk	Increased investment in common technology (can also be a higher risk)	Meyer and Lehnerd (1997)
Design	Shared development cost (intended commonality)	Reduced engineering effort required for later variants	Meyer (1997), Ho and Li (1997), Johnson and Kirchain (2010)
	Reuse of already designed components and systems (unintended commonality)	Design effort does not need to be repeated	Ulrich and Ellison (1999)
	Reuse of proven technologies	Reduces technology risk and mitigation cost	Robertson and Ulrich (1998)
Manufacture	Shared tooling	Tooling cost can be spread over more products	Lehnerd (1987), Park and Simpson (2005)
	Learning curve benefits	Fewer hours/unit required	Park and Simpson (2005)
	Economies of scale in manufacturing	Enables movement to higher volume methods	Robertson and Ulrich (1998), Krishnan and Gupta (2001)
	Bulk purchasing	Discounts from suppliers for larger orders of same part	Robertson and Ulrich (1998), Simpson (2004)
	Reduced inventory	Lower safety stock levels due to demand aggregation	Collier (1981), Baker et al. (1986)
	Reduced quality expense	Fixed quality expenses spread over larger volume	Sanderson and Uzumeri (1995)
	Flexibility in variant volumes (for a fixed platform extent)	Enables the firm to adjust to variant demand changes	Suárez et al. (1991), Robertson and Ulrich (1998)

(continued)

Table 2.1 (continued)

Phase	Benefit	Rationale	References
Testing and commissioning	Reduced testing and commissioning time	Learning in test procedures for later variants	Park and Simpson (2005)
	Shared testing equipment	Testing equipment can be spread over more products	Robertson and Ulrich (1998), Park and Simpson (2005)
	Reduced external testing/certification	Reuse of type certificates or regulatory approval	Rothwell and Gardiner (1990), Sabbagh (1996)
Operation	Reduced sustaining engineering	Number of parts to be sustained is reduced	Fixson (2006)
	Decreased fixed costs from shared facilities	Sharing of facility cost across more products	Fixson (2006)
	Decreased operator training	Operator learning on common parts reduces training	Halman et al. (2003)
	Economies of scale in operations	Move to higher volume operating procedures	Halman et al. (2003)
	Bulk purchasing of consumables	Discounts from suppliers for larger order of same parts	Robertson and Ulrich (1998), Simpson (2004)
	Decreased variable costs due to more efficient logistics and sparing	Reduced inventory for operations	Collier (1981), Baker et al. (1986)
	Slower replacement rate for spares (higher quality)	Fewer spares must be purchased	Sanderson and Uzumeri (1995)
	Flexibility in operations	Ability to switch operating staff between products	Halman et al. (2003)
	Shared inspections/recurring regulatory compliance	Lower cost and less time required for regulatory compliance	Rothwell and Gardiner (1990), Sabbagh (1996)

In the design phase, commonality primarily acts to reduce the number of engineering hours required to produce a variant (Ho and Li 1997; Johnson and Kirchain 2010). Intuitively, this can be understood as engineers producing fewer unique parts. However, as seen under Costs of Commonality, common parts often take more time to design, so the effort required must be carefully sized. In addition to producing fewer parts, design hours are reduced when effort in product definition (requirements and goal setting) can be reused, when design analysis methodologies can be reapplied to slightly different parts or environments, and when challenges in the initial variant design inform design strategies for unique parts on later variants. The reduction in engineering effort is primarily measured in engineering head count or engineering hours. While these may appear to be easily applied summary measures, the realities of accounting for reduced head count on a subsequent variant as traceable to early design effort can be complex to track (Ben-Arieh and Qian 2003).

In the manufacturing phase, commonality impacts many different departments involved in coordinating manufacturing. On the physical manufacturing line, platforms can enable the firm to move to higher volume manufacturing methods, such as from operator-assisted sheet-metal bending to fully automated operations. This is typically referred to as economies of scale, in reference to the idea that higher volumes allow new capital equipment to be amortized across higher volumes (Krishnan and Gupta 2001). This should be contrasted with learning curves on the manufacturing line, the idea that the labor portion of the manufacturing cost shrinks as assemblers find more efficient ways to complete the task and reduce quality expense when the resulting efficiency causes fewer defects, particularly when the platform is designed to the higher quality variant (Desai et al. 2001). Off the physical line, the purchasing department stands to gain leverage with increasing volume of common parts, and the supply chain department can stock fewer parts, as the aggregation of demand from different products for the same common parts lowers the safety stock that needs to be carried. Fixson (2006) notes that a number of supporting costs reductions are also achieved under commonality through lower product support activities, highlighting that commonality can have positive externalities on corporate overhead.

Benefits in testing and commissioning result from learning curves during repeated tests, amortized capital expenditure, and the potential for direct reuse of regulatory compliance tests. In the transportation and aviation markets, these benefits can be significant—reuse of an aircraft type certificate can save years in time to market.

Benefits in the operation phases are analogous to the benefits in the prior four phases. Table 2.2 shows a mapping of operation benefits to previous benefits, with the type indicated as a general categorization of the benefit.

Operations raise an important question about *who* benefits from commonality. For an aircraft manufacturer, which does not operate the products it produces, the benefits of commonality in operations will accrue to the operating carrier.

Table 2.2 Comparison of analogies to operations benefits

Phase	Type	Benefit	Operations Analogy
Design	Non-recurring labor	Shared development cost (intended commonality)	Reduced sustaining engineering
	Non-recurring labor	Reuse of already designed components and systems (unintended commonality)	
	Technology reuse	Reuse of proven technologies	
Manufacture	Capital	Shared tooling	Decreased fixed costs from shared facilities
	Capital	Economies of scale in manufacturing	Economies of scale in operations
	Volume	Learning curve benefits	
	Volume	Bulk purchasing	Bulk purchasing of consumables
	Volume	Reduced inventory	Decreased variable costs due to more efficient logistics and sparing
	Quality	Reduced quality expense	Slower replacement rate for spares (higher quality)
	Flexibility	Flexibility in variant volumes (for a fixed platform extent)	Flexibility in operations
Testing and commissioning	Non-recurring labor	Reduced testing and commissioning time	Decreased operator training
	Non-recurring labor	Reduced external testing/ certification	Shared inspections/recurring regulatory compliance
	Capital	Shared testing equipment	

For example, airlines that operate Airbus A319, A320, and A321 aircraft can leverage the common glass cockpit instruments for shared training savings and the corresponding flexibility in pilot assignment (Brüggen and Klose 2010). While these savings will not accrue to the aircraft manufacturer directly, commonality is often used as a sales and marketing strategy. If the aircraft manufacturer can produce convincing calculations of fleet savings in operations from commonality of new aircraft with the operating carrier's existing fleet, commonality can be used as a sales advantage to boost units sold.

Having now identified the benefits of commonality, it is important to ask the question how big the benefits are. Our research (Cameron 2011) suggests that the benefits vary widely across industries, depending on the cost structure, clock-speed, and number of competitors. Well-executed commonality strategies can produce 15–50 % savings, while poorly executed platforms can *add* cost and overhead to products. To help understand which benefits are most likely to dominate, Fig. 2.2 illustrates two broad firm cost structures.

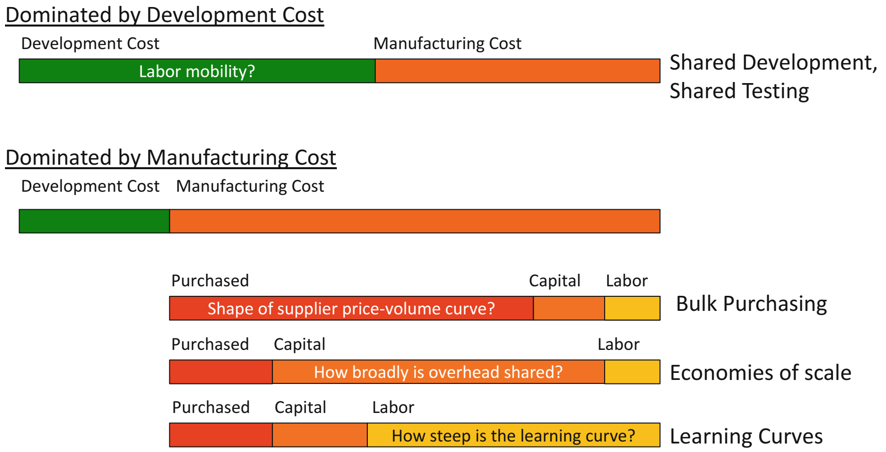

Fig. 2.2 Illustration of conceptual model of commonality benefits

2.3.1 Industries Dominated by Development Cost

Two criteria emerge in industries with large development cost (and typically low production volumes). The first criterion is that the saved development labor can either be productively placed elsewhere or it can be cut. It is typical to employ large-salaried workforces in several of the industries studied (e.g., Aerospace, Heavy Equipment). If the reduced head count required for later variants is not productively redeployed, the firm will not save any money. Challenges redeploying were found in organizations with high product-to-product walls and those with very dissimilar product lines.

The second criterion is that the business model does not depend on cost-plus (or similar) contracts. A number of Aerospace and Transport firms operate, or have historically operated, under design-for-fee contracts, which make it difficult to charge higher margins on later designs. This contract structure is often coupled with the practice of modifying scope or requirements (as previously discussed), which also inhibits development cost savings.

2.3.2 Industries Dominated by Manufacturing Cost

We propose the following three possible criteria, each of which can individually create a financially beneficial platform, although there are many possible strategies targeting individual benefits.

- Criteria 1—Significant learning curves are possible. This typically implies direct labor is a significant fraction of total lifecycle cost and also that volumes are sufficiently large to reach these learning curves. Platforms where only 1–2 %

learning curves from aggregating volumes can be achieved are unlikely to merit platform investment. Similarly, industries where configuration complexity is likely to swamp learning benefits are unlikely to retain benefits.

- Criteria 2—Strong bulk purchasing discounts are available. In industries that purchase a large fraction of product cost, as in Automotive, platforming will only be beneficial if there is a strong potential for a discount. If the firm cannot aggregate over sufficiently large volumes, or the suppliers have monopolies, it will be difficult to achieve a meaningful discount. In an Automotive case we conducted, several subsystems did not have sufficient visibility into their supplier's cost structure in order to assess whether a discount could be achieved.
- Criteria 3—Investments in economies of scale and capital equipment will outlast the platform. Particularly in industries that are capital intensive, if the industry clock-speed dictates new manufacturing methods on short cycles, it will be challenging to invest. This is potentially the situation in semiconductor manufacturing, although Boas (2008) illustrates how, from the perspective of the manufacturer of the capital equipment (as opposed to the purchaser and user), there are sufficient projections to merit platform investment.

2.4 Costs of Commonality

The costs of commonality are widespread and must be carefully considered before engaging in a multiproduct strategy. Fundamentally, any commonality strategy involves significant upfront investment, in order to define the platform and create the common components. However, there are a number of costs and drawbacks that occur through the different lifecycle phases, each of which poses a risk to the successful execution of this strategy. Unrealized costs and unanticipated challenges have derailed many platforms in our experience.

We have divided the costs and drawbacks of commonality into five categories, as with the benefits, and they are summarized in Table 2.3. This list includes both direct, quantifiable costs and broader strategic drawbacks, which are difficulty to indirectly cost but represent real challenges all platforms will face. Each cost and drawback is labeled as recurring or nonrecurring with respect to additional variants. For example, the design premium is a nonrecurring cost, in that it is invested once at the beginning of the program, and can be leveraged on each variant. By contrast, the capability penalty (defined as the over-performance and cost compromises of commonality with other variants) is a recurring cost, in that it affects each variant.

Not all of these costs are expected in all commonality projects—for example, commonality may reduce the labor content in assembly, rather than increase it. This is not to say that these costs are small or easily mitigated. Most execution challenges in common programs manifest as cost problems at some point, whether it be in underestimated commonality premiums in design phases or in pro-divergence arguments based on reducing the unit cost during manufacturing.

Creating realistic projections of these costs is a competitive advantage for firms which successfully employ commonality strategies, as these projections enable the

Table 2.3 Commonality drawbacks, costs, and risks (Note: the costs do not materialize universally; rather, the potential for costs to exist has been demonstrated, and the third column provides guidance on whether the cost recurs with each successive variant within the original platform extent or the individual cost behavior will vary by platform)

Phase	Drawbacks and costs	Recurring?	References
Strategy	Constraining future investment to platform extent	NR	Henderson and Clark (1990), Halman et al. (2003)
	Development plan risk from shared components	R	Henderson and Clark (1990)
	Brand risk from lack of differentiation	R	Kim and Chhajed (2000), Jans et al. (2008)
	Risk of cannibalization	R	Sanderson and Uzumeri (1995), Kim and Chhajed (2000)
	Risk of monopoly by common system provider	R	Swift (1995), Burke et al. (2007)
Design	Investigating technical and economic feasibility	NR	Ulrich and Eppinger (2004)
	Design premium for satisfying multiple needs	NR	Halman et al. (2003), Ulrich and Eppinger (2004)
	Costs of integration	R	Erixon and Ostgren (1993), Du et al. (2001)
	Commonality management overhead	R	Muffatto (1999), Sundgren (1999)
Manufacture	Increased cost of common items due to capability penalty (materials cost and labor cost)	R	Krishnan and Gupta (2001), Nobelius and Sundgren (2002)
	Increased complexity of configuration management on the manufacturing line	R	Thonemann and Brandeau (2000)
	Carrying costs of production assets with higher than necessary initial capacity (offset development)	NR	Thonemann and Brandeau (2000)
	Commonality management overhead	R	Muffatto (1999), Sundgren (1999)
Testing and commissioning	Cost of creating more capable test environments	NR	Halman et al. (2003)
Operation	Risk of common part failure, affecting multiple products	R	Meyer and Lehnerd (1997), Halman et al. (2003)
	Increased complexity of operating a multi-purpose item	R	de Weck (2003)
	Carrying costs of operating assets with higher than necessary initial capacity (offset development)	NR	Meyer and Lehnerd (1997)
	Commonality management overhead	R	Muffatto (1999), Sundgren (1999)

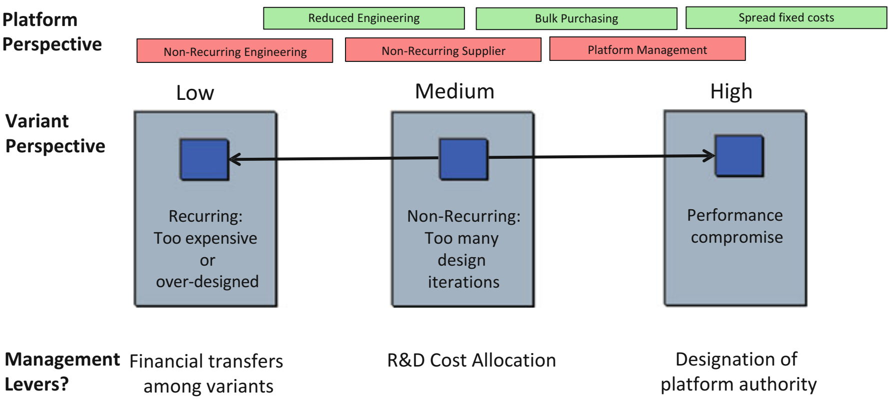

Fig. 2.3 Arguments raised by variants that can lead to variants suboptimizing the platform

firm trade investment against the potential return and also to plan for appropriate management resources in design, manufacturing, and testing.

Past research (Ulrich and Eppinger 2004; Halman et al. 2003; Cameron 2013) suggests that the upfront investment in platforms can be multiples of an individual product design effort. If a platform of three products costs $200 million compared with three individual products at $100 million each, the savings are significant ($100 million), but the initial investment is still twice the size of a typical development program. We define this initial investment as the commonality premium—the ratio of platform development cost to a single product development cost. Ulrich and Eppinger (2004) suggest 2×–10× as the premium. A subsystem-level study (Cameron 2011) in the context of a 3-case study of low-volume capital-intensive manufacturing firms indicates that the system premiums ranged from 12 % to 50 % for three platform in transportation, with subsystem premiums as high as 200 % (3× a single product subsystem development program).

These costs do accrue evenly to all products on a platform. For example, the upfront variant is likely to pay most of the commonality premium, unless the platform is explicitly structured to share investment (Meyer et al. 1997). Savings from amortized capital equipment are more likely to accrue to later variants. This imbalance implies that tensions will arise between variants—some variants will create investments that they will not be able to recover themselves. Therefore, in addition to the necessity of weighing the costs of platforming against the benefits, it is important to create a platform perspective on costs. Without a platform perspective, individual variants will systematically reject the compromises and additional costs inherent in a platform strategy in favor of lower-entropy, individualized design.

Figure 2.3 illustrates how some of these costs can be projected on to individual variants, which are arranged for a vertical platform strategy (economy to luxury products). The position of the product within the platform extent (the performance range spanned by the variants) determines which of the benefits it stands to gain, as well as which of the costs it may have preferred not to shoulder. For example, the low performance variant typically aims to minimize unit cost to provide the lowest possible entry price into the market (de Weck 2006) and will therefore attempt to reject common components with heavy capability penalties or hooks for expensive options. Figure 2.3 illustrates the most common source of complaint for each variant in the platform extent.

2.5 Planning for Divergence

Despite significant investments and planning efforts, many platforms tend to realize less commonality than intended, a phenomena we call "divergence." This phenomenon appears to affect platforms across industries, ranging from automotive to semiconductor capital equipment as summarized in Table 2.4. There is a large body of work on developing commonality metrics (Wacker and Treleven 1986; Siddique et al. 1998; Jiao and Tseng 2000; Thevenot and Simpson 2006), but descriptive studies tracking commonality indices over time are just beginning to emerge (Fixson 2007). A widely cited example is the Joint Strike Fighter, a military aircraft designed with three variants, which was intended to share 80–90 % parts commonality across all three variants. Through development and early production phases, commonality fell sharply to 30–40 % parts shared (Boas et al. 2012).

The magnitude of this phenomenon is not static across industries or platforms. Some platforms see minimal erosion of targets, while others face strong pressure to move towards unique designs. Our understanding of the challenges would suggest that divergence varies much more strongly in response to a firm's management capabilities than in response to the market in which the firm operates.

Boas et al. (2012) illustrate that divergence is not necessarily an entirely negative phenomena. For example, an optimistically scoped platform would benefit by moving to more achievable commonality level, potentially seeing reductions in development budget and schedule. Likewise, beneficial divergence can occur in the face of unanticipated technological progress or when market requirements change during the design process. Ramdas and Randall (2008) find that uniquely designed components have higher component reliability, eschewing the design compromises associated with commonality.

However, there are also negative implications from divergence. Any movement to lower commonality levels implies more unique content, which will require design work, manufacturing planning, and operational constraints. In addition to the incremental work implied, divergence reduces the extent of the cost synergies on which many platforms were founded (Cameron 2011).

Divergence results from a number of imbalances that recur in most platforms. These imbalances occur in time, resources, volumes, and markets. Almost all platforms contain some degree of time offset, where one variant is designed and manufactured before others. This lead variant has a strong influence on the platform, often shouldering the design of many of the common parts. Difficulty understanding the future needs of latter variants can cause the lead to skew the common design closer to its needs, thus creating an opportunity for divergence when latter variants inherit the skewed parts. Similar imbalance in development

Table 2.4 Research data categorization of observed divergence together with the range of offsets, reproduced from Boas et al. (2012)

	Automotive	Military aircraft	Commercial aircraft	Business jets	Printing press	Comm. satellite	Semiconductor capital equip.
Divergence	High	High	Moderate	Low	Moderate	High	Moderate
Offset as % of development time	100 % (24 months)	10 % (6 months)	25–280 %	0–125 %	75–250 %	0–170 %	0–130 %

budgets, expected production volumes, and perceived customer importance also creates opportunities for divergence.

Making strong decisions in the face of divergence is the result of understanding the differential impact on the benefits and costs of commonality. We've already established that all divergence has a near-term cost, due to implied unique design work, and a long-term cost, due to reduced synergies. However, the downstream positive revenue implications may dwarf the near- and long-term cost of divergence.

For example, consider a rail manufacturer attempting to produce a platform locomotive, spanning three national operating voltages. If one of those national markets changes voltages to double its existing specification, the rail manufacturer should weight the relevant implications on costs and benefits. Modifying the platform to include new operating voltage may significantly increase the commonality premium, as the design may need to be reworked. Additionally, it may raise the cost of manufacturing for all locomotives due to the capability penalty. By contrast, the manufacturer can consider diverging, creating a new locomotive targeted at one market, and reducing the existing platform specification to two voltages. This implies that there will be a lower bulk purchasing effect for the platform, because common components will not be spread across three national markets. This decision would create additional design work for the new locomotive, but it may also reduce the commonality premium for the platform, as fewer design constraints are levied. The rail manufacturer will need to weigh these costs and benefits against the revenue implications of the decision. They may in fact sell more locomotives in the remaining two national markets if they can pass the reduced commonality capability penalty on to the consumer in the form of a lower price.

Our research suggests that the firm's ability to weigh the options in a divergence decision represents a key competitive advantage for firms. Cameron (2011) illustrates the mechanisms by which divergence led to failed investment returns on large platforms. By contrast, firms like Volkswagen, which has pursued multiple product platforms, are continuing to achieve cost savings on the order of 30 % and lead time reductions on the order of 50 % (Pander 2012).

Having now illustrated that divergence opportunities need to be carefully weighed, we must ask the question of whether upfront planning should anticipate divergence. We have already illustrated that commonality planners should include sizeable commonality premiums in design phases, and we have identified downstream potential savings in supply chain, manufacturing, testing, and operations.

Our research suggests that estimating realistic commonality benefits is a firm competence. One Automotive firm we worked with kept detailed variant cost estimation models, which would project the design work required to produce a derivative (such as a long wheelbase model), as a function of the binned magnitude of changes and the complexity of the host platform.

Should platform managers actively slash projected savings and inflate commonality premiums to account for divergence? Should they assume an "average divergence" factor? We have not seen evidence in industry that this is an effective practice, beyond the standard practices of planning for program manager reserves and estimating schedule risk. Rather, the approach followed by successful firms has been to keenly question commonality plans, attempting to pare the design down to retain feasible commonality levels. Recast in another light, stretch goals are an important practice, but they should be used incrementally rather than radically as applied to platforms.

2.6 Choosing a Platform Strategy

The choice of what to make common is at the heart of any platform strategy. Fundamentally, this choice must be grounded in technical reality. For example, it must be feasible to use the same water valve in three different radiators. However, the choice of platform strategy must be grounded in, and clearly traceable to, a set of financial advantages. This implies some degree of coordination between technical and financial decisions. For example, aggregating water valve purchasing across the firm to establish supplier orders of 10,000 rather than orders of 1,000 may enable a strong bulk purchasing discount.

In this section, we identify some of the canonical commonality strategies, and we compare them against the associated benefits. In parallel with this analysis, it is important to conduct the market research and planning to establish differentiation across the product family, but for the purpose of linearity, this is not discussed in detail here.

Table 2.5 lists a subset of the available platforming strategies, arranged from low commonality planning effort at the top to high commonality planning effort at the bottom. For alternative categorizations of commonality strategies, see Robertson and Ulrich (1998) and Park and Simpson (2005).

We can see from this list that pervasive commonality strategies tend to target development benefits but invest significantly up front in order to achieve this benefit. Lower-order strategies, which tend to be organization-wide rather than platform-wide (Labro 2004), are more likely to cite bulk purchasing and inventory charges. Separate from the question of whether commonality is technically feasible, it is important that the platform manager align the firm's commonality strategy with its cost structure. For example, if consolidating all the low-cost components from the firm's three product lines would double the effective volume purchased from the firm's steel supplier, the question remains whether the steel supplier would offer a discount at this volume. If the steel supplier can only make meaningful changes to cost structure based on 10$\times$ volume, then the investment in consolidating low-cost components is unlikely to bear out. Farrell and Simpson (2010) offer a methodological step in this direction, using activity-based costing to understand how consolidation of components impacts manufacturing economies.

In terms of challenges, diffuse low-order commonality strategies clearly face greater coordination challenges and specifically are more likely to face funding challenges. Higher order commonality strategies are more likely to face "execution" challenges, in terms of holding off unplanned customization (Wortmann, et al. 1997). These challenges will create divergence opportunities in all cases, whether they

Table 2.5 Platform strategies arranged from low forward planning (top) to high forward planning (bottom)

Strategy	Applicability	Benefit	Challenges
Reactive reuse (Siddique and Repphun 2001)	Low planning ability	Development	High risk of optimal solutions
	Low R&D spending	Tooling	Potential for missed benefits
Low cost components (Labro 2004)	Flat component curve	Bulk purchasing	Hard to define fixed cost savings
	Low planning ability	Inventory	Assumes labor mobility across products
Building blocks (Fisher et al. 1999)	Stable architecture	Bulk Purchasing	Challenging to synchronize development
	High overhead	Inventory	Difficult to fund R&D
Non-differentiating subsystems	Stable architecture	Development	Managing stable interfaces
		Testing	Enabling differentiating features
High cost components (Boas 2008)	Steep component curve	Testing	Risk of high integration costs
	High R&D spend	Economies of scale	Degradation to reactive reuse
Backbone/common architecture (Halman et al. 2003)	Low clockspeed	Development	Risk to development savings—customization
	High R&D spend	Economies of scale	Does not imply testing savings
Commonality culture (Boas 2008)	High planning ability	Development	High coordination costs
	High R&D spend	Inventory	

Divergence data is binned from low to high, where low represents small changes, such as moving from 80 % of parts shared to 77 % of parts shared, and high represents changes on the order of decreases by 50 % (half of the intended common parts became unique parts). Not all calendar offsets (number of months) can be given due to confidentiality concerns (Boas et al. 2012)

manifest as product managers lobbying for exemption from high coordination costs shared via overhead or variants attempting to shirk high integration costs by moving to unique solutions. Astute program managers will also recognize that these challenges will be increasingly back-end loaded on platform timelines for higher order commonality strategies, while lower-order strategies will face more challenges upfront in aggregating diffuse product teams into ordered component strategies.

This representation of commonality strategies does not capture the complexity of the product architecture (Baldwin and Clark 2000)—it does not represent the modularity of the platform, the intended servicing functions, or the organizational implications. However, it does showcase the necessity of matching commonality strategy to an expectation of cost and benefit. Firms that attempt to commonalize as much as possible, without regard for expected benefits and implied costs, will find themselves incurring almost all of the commonality cost categories listed here and almost certainly swamping the expected benefits.

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