*An executive summary for managers and executives can be found at the end of this article*

# Designing products for variety and how to manage complexity

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## Introduction

The combination of new and old practices, such as old-fashioned habits, new life-cycle environment, changes, and mounting regulations, has increased the complexity of product development efforts. The complexity results from five main sources:

(1) inherent product complexity;

(2) process complexity;

(3) team co-operation and communication complexity;

(4) computer and network complexity; and

(5) a maze of specifications including international regulations and safety.

### Changing market conditions

Over the past several years the diversity, variety and complexity of New Product Introduction (NPI) have grown multi-fold from "very simple" to "very complex" while, at the same time, the time-to-market aspect has shrunk (Prasad, 1994). This is shown in Figure 1. The changing market conditions (such as global manufacturing, the global economy, and new innovations) and international competitiveness are making the time-to-market a fast shrinking target. Today, an automobile with complexity several times higher than before can be brought to manufacture in less time (often less than three years). The same product, about half a decade ago, used to take over five years to bring into the marketplace. However, its complexity ten years ago, by today's standards, could be characterized only as "very simple."

The computer workstation market is another good example. With innovations in chip technology, computer workstation companies have continually shortened the time between new product introductions. In 1985, when a new central processing unit (CPU) was introduced, it was quite innovative – but was nowhere close to today's standard in complexity. Every 18 months thereafter, a new CPU, twice as complex, was introduced having two times the performance at roughly half the price. In 1988, four times more complex and four times faster CPUs were introduced at a quarter of the price in a 12-month period. In 1990, the development cycle for a new 16 times faster CPU was only six months nearly at 1/16th of its 1985 price. The trend goes on. The average development time for a compact disc (CD) player today is nine months, a PC is 14 months, a knowledge-based engineering (software development) system ranges from two-four years.

Amongst the web of such complexity, it is easy to overlook that requirements of the customer are also constantly changing. The customer is also becoming more sophisticated. Each time a company fulfills customers' wants in a product, the level of customers' expectation also moves up a notch. They demand customized products more closely targeted to their personal, social and cultural tastes. The same is true for expectations about performance (Prasad, 1996). Products get old quickly – customers' excitements fade away, and demands decline. There is a great danger that a

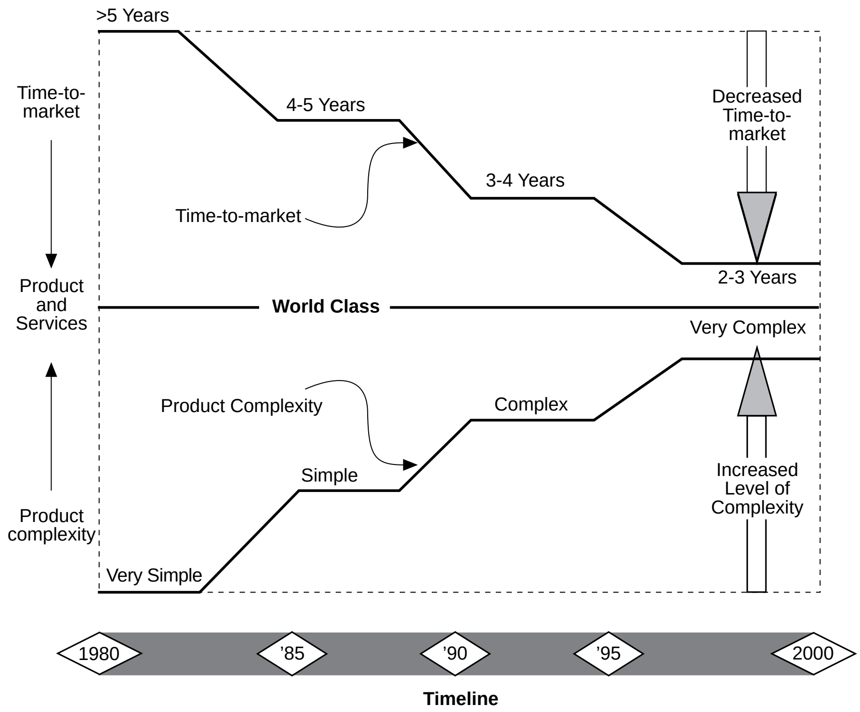


*Figure 1. A case of a constantly moving target*

product introduced after a few years of its development may not remain attractive for the market that existed at the launch time. Introducing a new product at frequent intervals is also not a good business solution. New products require significant investments in redesign, retooling and manufacturing costs. Development costs consist mostly of expenditures for staff and testing. These costs tend to increase proportionally with the overall time taken to complete the "production-ready" design. For this reason, most manufacturers have focused on shortening the time taken for new models to be designed and tested. Toyota, for example, has set its sights on reducing the average development time of its automobiles from 24 months to 18 months by 1998. The US Department of Defense (DOD) Computer-Aided Acquisition and Logistics Support (CALS) initiative identifies CE as an enabling technology that can help potentially lower development and operational costs while appropriately managing the moving targets.

## Product complexity

### Variety and complexity – an automobile example

Most auto companies introduce a new car model (one way to represent its variety) every two-three years at a cost of a billion dollars per vehicle. The cost of the vehicle may represent, in this case, a dimension to measure its *process complexity*. The new car development program in the USA now ranges between three to four years, whereas in Japan it takes less than three years. (Time, in this case, may be viewed as another dimension of *process complexity*.) Development is generally the responsibility of the operating platform groups, with new product sold by one or more of their marketing units (showing team co-operation and communication complexity). The major elements of an automobile (*showing product complexity* ) are:

- *Outside body:* it includes major designs for outside body parts, structures such as roof, moveable roof, body glass, quarter panel, fender, A-pillar, B-pillar, C-pillar, decklid, trunk, apron, shot-gun, vehicle tools, paints, etc. They are often designed by a staff group:

- *Styling* is done by a central design staff with support from components' divisions and outside suppliers. They come up with the design of the outside contour, look and feel mostly from aesthetic considerations.
- *Detail design* of the parts and body panels are done by the CAD/CAM shop contractors.
- *Analysis* is proposed by the engineers but often performed by the analysts on contracts.
- *Tooling and dies* are handled by process engineers internally and by outside prototype shops.

The following are done by a prototype shop, one or more of the components' groups, or first- and second-tier suppliers:

- *Interior systems:* instrument panels, air bag, steering wheel, door trims, door modules and related hardware, latching, window regulators, power closures, power sliding door, seat systems – seat trim, adjusters, recliners, frames, head rest, arm support, etc.
- *Vehicle wiring systems:* ignition wiring, fiber optic data transmission, fiber optic lighting distribution, electrical/electronics connection, multiplex, wire harness – integration of electrical electronics into modular structures, temperature sensors, electronic modules and switches.
- *Brake systems:* anti-lock brake, traction control, intelligent brake control, power brake assemblies, electric brake, disc and drum, corner assemblies, wheel spindle bearings, knuckles, calipers and rotors, etc.
- *Suspension systems:* suspension assemblies, controlled suspension, structural composites, integrated chassis, module suspension, powertrain mounts, etc.
- *Climate control systems:* heating, ventilation and air-conditioning, condensers, compressors, accumulator dehydrators, evaporators, heater cores, etc.
- *Engine/transmission cooling systems:* radiators, oil coolers, engine cooling module, etc.
- *Engine management systems:* air fuel, ignition, fuel handling and evaporative emissions, electronic control modules and algorithms, exhaust system, valve train, etc.
- *Energy management system:* power generation and storage, batteries, generators, sensors and solenoids, electric vehicle, etc.
- *Lighting systems:* forward lighting, signal lighting, center high-mounted stop lamps, distributed lighting, high intensity discharge lamps, etc.
- *Vehicle control systems:* advanced steering, power steering, pumps, gears and hoses, variable effort steering, standard and adjustable steering columns, intermediate steering shafts, etc.
- *Driveline systems:* axles, front and rear, propshaft, halfshaft assemblies, constant velocity joints, intermediate drive shafts, boot seals, etc.
- *Engine:* structural, crankdrain, valve train, cam drive, accessory drive, lubrication system, cooling system, air intake, PCV, combustion, exhaust, sealing and fastening assembly, etc.

- *Transmission systems:* transmission (auto and manual), torque converter, case and cast components, gears and shafts, mechanical components (clutches, free wheelers, chain drive), cooling and lubrication, sealing and fastening, dress components, transfer case, etc.
- *Powertrain controls and diagnostics:* diagnostics, electrical, electronics, software, driver display, driver controls, sensors, actuators, other miscellaneous systems.
- *Others:* entire program is supported by thousands of second- and third-tier suppliers that provide interior parts, bolt-in parts, and hundreds of other components and materials.

**Assembly plants**

One may consider the above elements describing automobile *product and process complexity*. An operating group or platform normally is responsible for a particular line of automobiles – small or sporty cars for example. The corporation generally has engineering facilities at multiple cities and has assembly plants in multiple countries (such as USA, Canada and Mexico). This shows that, in such cases, a *maze of specifications would be required including international regulations and safety*. Many of its plants are spread throughout the USA (e.g., the Midwest and South). Operations within an operating group are supported by an extensive vendor network or a supply chain. This shows the level of *computer and network complexity* that would be required.

During this three years' cycle of a new vehicle or product development process, an operating group or a platform must also build other car lines. This means, in the current year 199X-199X+1 (this means, for 1997, X = 7), manufacturing engineers would be building 199X+1 (1998) models' car, while process engineers will work on 199X+2 (1999 if X = 7) models, and product engineers concern themselves with 199X+3 (2000 if X =7 ) product lines. Other groups within the company must support these four groups: design group, process group, manufacturing group, and the operating group. For instance, design support groups may seek a balance among piece cost, manufacturing, assembly, fuel consumption (mileage), emission and safety regulations. The planning group may balance investments with budgets. Marketing groups may seek competitive concerns, such as styling, vehicle content, quality, and numerous other issues (*showing process complexity*). These groups are often within a matrix together to address these concerns. Since many of these groups are independent of each other, no one manager is likely to own the right or control the total program. This means team co-operation and communication complexity would be quite extensive. Funding and control of resources are usually decided through committees. Each group, thus, ends up doing (sub-optimizing) their own things with lack of overall co-ordination between the groups. The problem is typical of a situation where groups have too much independence but not enough co-ordination.

## How to manage product complexity

**System complexity**

There are a number of approaches to dealing with system complexity that have evolved in the last couple of decades. The automobile example – discussed in the previous section – gave some particulars about product, process, system and network complexity. Towards solving problems of system complexity, an initial attempt goes back to 1964, when Alexander proposed partitioning the "design process" into a set of minimally coupled groups (Alexander, 1964). Simon (1981) later suggested that product complexity can be handled by dividing the original problem into a set of *"nearly decomposable groups"*. These groups could be organized as hierarchical structures such that the strongest interactions occur within groups and weaker interaction occurs across groups (Simon, 1981). One such approach commonly used by product designers is to decompose the original product system into a set of hierarchical structures. For example, the product may be decomposed into hierarchical sets – from subsystems to components, to parts, to materials/attributes/features/parameters, and then finally to a set of common representations and standards (see Figure 2). The so-called product breakdown structure (PtBS) (Prasad, 1996), in that case, forms the basis for the hierarchical descriptions of the CE design process. This type of decomposition would be the same for a product whether the CE design process is tightly coupled or highly integrated.

PtBS tree ⇔ *[Class descriptions of the product tree breakdown structure]* (1)
*(Subsystems, components, parts, materials/features/parameters, common representation and standards)*

Where ⇔ represents the equivalence of the two sets as defined. Each parent class can be further decomposed into their children. The breakdown of the part definition tree, for example, has two main elements: the primary features class and the materials specification class (see Figure 3).

Parts tree ⇔ [Class description of the part ] (2)
(Primary features, the materials, etc. )

**Primary features**

Primary features define the basic shape of the part by progressively chaining the lower-level characteristics (a set of form features and assembly information). Non-geometric information, such as tolerance and surface finish quality, can be assigned as attributes to the form features' class. Five types of form features are readily discernible in mechanical products: atomic, simple, compound, pattern and nary (Taylor and Henderson, 1994).

Form features ⇔ [Atomic, simple, compound, pattern, and nary] (3)

The material specification class defines the identifying characteristics such as material, type, compositions, material properties (E, $v$, ρ, σ, ..., etc.), and material treatments (heat, chemical and surface treatments). Process information (such as equipment, procedure and method used to manufacture the parts), is assigned as an attribute to the materials class.

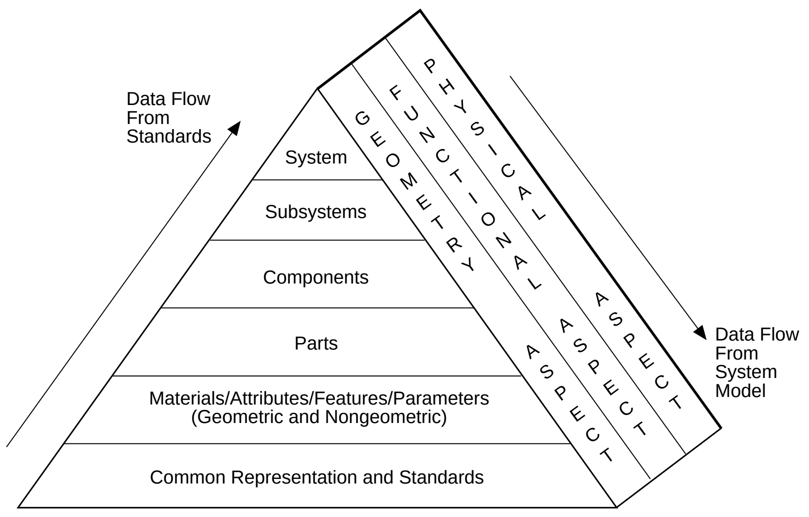


*Figure 2. Hierarchical decomposition of a product*

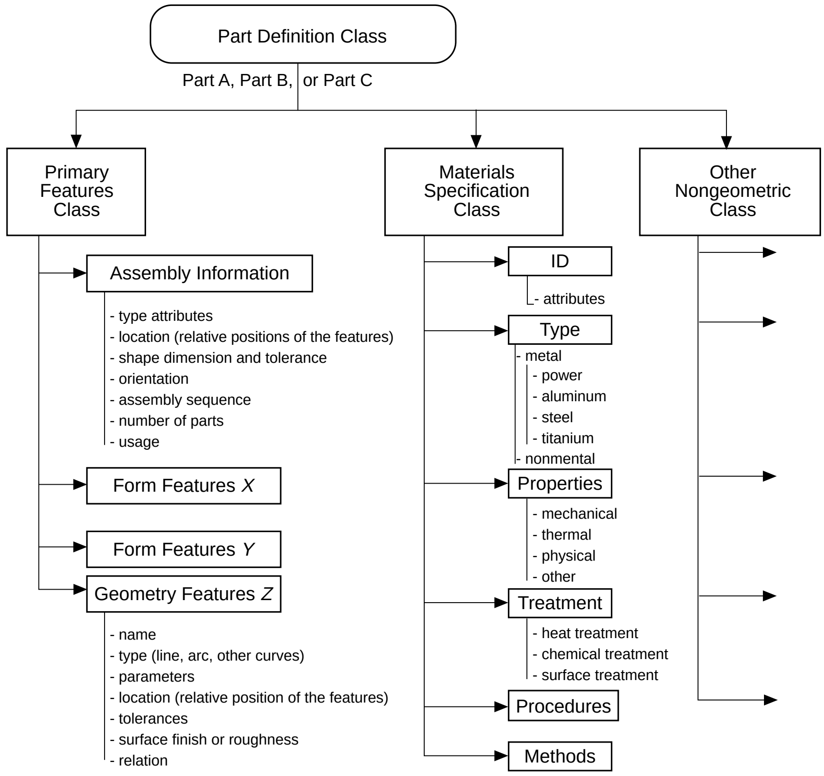


*Figure 3. Elements of part definition class*

### Optimizing values while designing product for variety

**Product variety**

Variety means packaging together a number of functions/features in a single part. As functions per part increase, each part becomes more complex but the total number of parts in a product decreases. Product variety has the effect of decreasing the volume-related costs, while increasing the complexity- related costs (Prasad, 1997). It costs more to manufacture a part that has many functions and features built into it. The focus here is not only on minimizing the product volume- and complexity- related costs but optimizing values. “ Optimizing values” is meant here to include shortening time to market, adding customer values, providing product functionality in addition to “minimizing cost.” For example, shortening time to market may not be just for cost reduction; it could provide a competitive marketplace advantage as well. If the cost would have been the only consideration in product variety selection, one could easily achieve a lowest cost by designing with a variety = 1.

Figure 4 plots two curves on the same graph as follows:

(1) *Part cost – curve a:* it shows the trend/variation of complexity-related cost with respect to the number of functions/features that can be packaged in a part. The trend is shown by a solid line in Figure 4. It may be noticed that part cost is low (this is designated by a point U) when the number of functions/features packaged per part are low. The part cost is high (this is designated in Figure 4 by point V), if the number of functions/features packaged per part are high. The points U and V on “curve a” would fluctuate; however, this trend would remain more or less the same for each part, irrespective of the part industry.

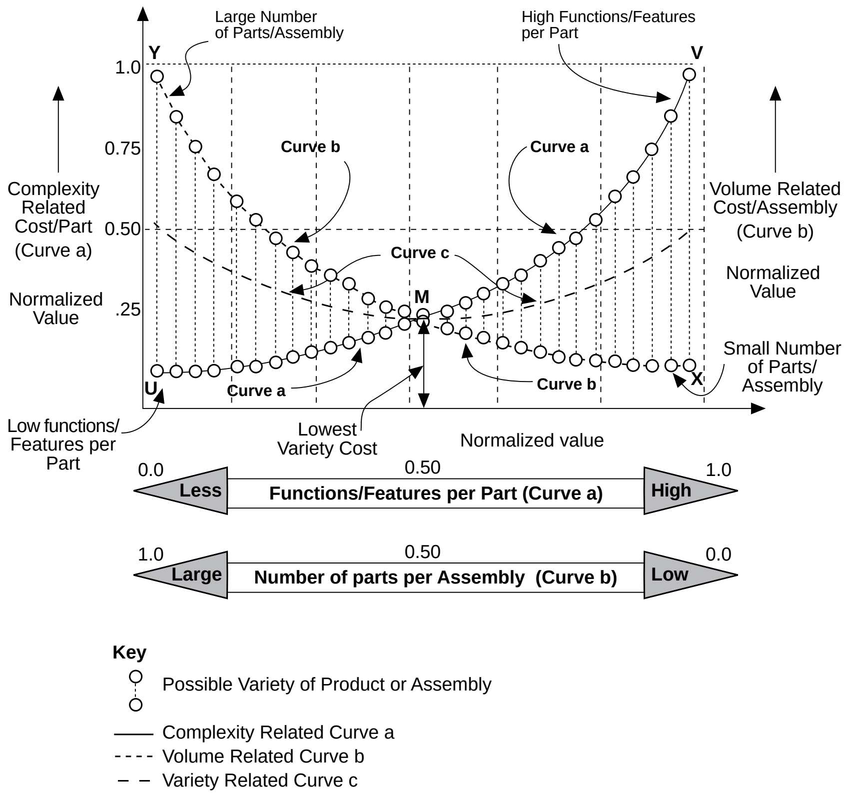


*Figure 4. Design for lowest variety cost*

(2) *Assembly cost – "curve b":* it shows the volume-related cost per assembly – through a chain line in Figure 4. A volume-related cost for an assembly depends on how many parts can be packaged in a typical product assembly for that assembly to be functional. If fewer parts are required to manufacture a product, the corresponding volume-related cost for that assembly would be small. This is indicated by point X on curve b. However, if a large number of parts will be required to provide an equivalent product (assembly) functionality, the volume-related cost for that assembly will be high. This is shown by point Y on curve b.

**Providing an asset**

### What constitutes product variety?

Product variety is the result of assembling parts to provide a set of useful functions, which the customers like or perceive as "valuable or wholesome." The range of such possibilities (variety) is quite large. This is shown in Figure 4 by a series of dotted straight lines vertically connecting the points along the two curves described earlier: curve a and curve b. The series of points along this vertical dotted line shows the range of product variety that is possible with a particular combination of product complexity and volume. If a part by itself can be leveraged to satisfy certain customers' needs, this part can be looked upon as a viable "product" offering. This is possible if a large number of functions/features can be packaged in a part in such a way that the part itself represents a useful artifact to the customer in meeting his or her needs. In most customer situations, however, an assembly (by combining one or more of the its parts) would be more appropriate to cater for the needs of an average customer. If a large number of functions/features can be packaged in a single part, fewer parts are required to manufacture a product variety. The range of variety (product offerings) in such cases is shown by the heights of the verticals drawn on the right half of the diagram in Figure 4. However, if the number of functions/features per part is small, a large number of parts may be required to assemble a product for customer use with an acceptable level of functionality. A variety of products with that type of offering are shown through dotted verticals on the left half of the diagram in Figure 4. It is assumed that low function/features per part could be an acceptable variety offering for some customers.

**What constitutes a variety cost?**

**The cost of producing a desirable product**

The variety cost is the cost of producing a desirable product variety. The points along the dotted vertical line (see Figure 4) show the range of product variety with a particular combination of product complexity and volume. A series of vertical straight lines is drawn in Figure 4 vertically connecting the points along the curves a and b. The verticals (lines) on the right represent the variation of the costs when complexity (functions/features per part) is high and a small volume (number of parts per assembly) is contemplated to satisfy the customers' needs. The verticals (lines) on the left represent the variation of costs when complexity (functions/features per part) is low and a relatively large volume (number of parts/assembly) is required to satisfy customers' desires as regards the finished product. Clearly the mean variety cost is lowest when complexity (functions/features per part) is neither too high nor too low. The dotted "curve c" in Figure 4 shows a mean variation of the variety cost as complexity (functions/features per part) increases. This gives rise to four types of variety costs for the four quadrants identified as follows:

(1) *Many functions/features/part:* this refers to the variety costs when many functions/features per part are used in the variety solution. The range of costs in this quadrant corresponds to the verticals above the mean curve c on the right half of Figure 4. An upper bound on the variety cost is reached when the points fall right on the MV portion of "curve a". A lower bound on the variety cost is incurred when the points lie along the mean "curve c".

(2) *Large number of parts/assembly:* This refers to the variety costs when a large number of parts per assembly are used in the variety solution. The range of costs in this quadrant corresponds to the verticals above the mean curve c on the left half of Figure 4. An upper bound on the variety cost is incurred when the points fall right on the YM portion of curve b. A lower bound on the variety cost is incurred when the points lie along the mean curve c.

(3) *Small number of parts/assembly:* This refers to the variety costs when a small number of parts per assembly are used in the variety solution. The range of costs in this quadrant corresponds to the verticals below the mean curve c on the right half of Figure 4. A lower bound on the variety cost is incurred when the points fall right on the MX portion of curve b. An upper bound on the variety cost is incurred when the points lie along the mean curve c.

(4) *Few functions/features/part:* This refers to the variety costs when few functions/features per part are used in the variety solution. The range of costs in this quadrant corresponds to the verticals below the mean curve c on the left half of Figure 4. A lower bound on the variety cost is incurred when the points fall right on the UM portion of curve a. An

upper bound on the variety cost is incurred when the points lie along the mean curve c.

**Cost solutions exist for variety**

As discussed earlier desirability may range from a part cost to an assembly cost depending upon what the customer foresees his or her needs are. This means that a range of cost solutions exists for variety. The lowest cost of variety is achieved when one of the following is true:

(1) The variety corresponds to a point that lies anywhere on a portion MX of curve b.

(2) The variety corresponds to a point that lies anywhere on a portion UM of curve a.

The variety corresponding to extreme points U and X may not be good viable solutions. A question could be asked regarding the most cost-effective solution if both (a) and (b) are optimally satisfied. This yields a variety solution corresponding to point M in Figure 4. This point M corresponds to a variety, which is the result of packaging a small number of functions/features per part and then optimally assembling the parts thus packaged.

In order to apply this procedure to determine a range of variety and the variety cost, correspondence to the normalized value in Figure 4 needs to be identified. The product designers need to identify the four product variety cases (benchmarks) which correspond to four extreme points (U,V, X, Y) in Figure 4. The following product cases may be considered:

- A part having a high number of functions/features incorporated. This would identify the normalized value for point V.
- A part having few functions/features incorporated. This would identify the normalized value for point U.
- An assembly having a small number of parts incorporated. This would identify the normalized value for point X.
- An assembly having a large number of parts incorporated. This would identify the normalized value for point Y.

**Transformation matrix**

Figure 4 shows a normalized shape of the cost variations – it would be more or less the same for different products. However, the mapping (transformation matrix) for different products, companies or industries would be different. If one is interested in estimating the variety cost for a given mix of product (volume and complexity combination), the above procedure can be used, first, to determine the mapping (transformation matrix) of the actual product mix to the normalized chart in Figure 4, and second to identify the corresponding normalized point on the dotted curve in Figure 4. Then the same transformation matrix can be used to determine the un-normalized numbers for the product mix (complexity and volume combination).

### What drives the variety costs

There are three main factors that affect the costs of providing variety (Ishii *et al.*, 1995):

- *Number of options in a product variety:* the cost of manufacturing is proportional to the number of product variations. The fewer the variations the lower the cost for manufacturing.
- *How much the product is away from its finish (job number 1) stage, when a variety program is implemented:* if a product variety option

occurs closer to the end of the manufacturing process (say job number 1), it will have less impact on upsetting any of the upstream processes. However, if variation occurs in the early phase of manufacturing, such a variation option may require performing a greater number of subsequent operations, increasing the complexity and cost of all related downstream processes.

- How "painful" is it to change from one variety to another: an example would be changing a die or a paint color. If the change requires activating a number of things, such as different plant layout, an additional production line and a different supplier, it would be more time consuming. The more components are involved, the more costly it will be to manufacture the product for a large number of variety options.

If a parameter $\alpha_1$ is associated with number of options, a parameter $\alpha_2$ is associated with time measured from the finish stage (job 1), and a parameter $\alpha_3$ is associated with change-over efforts, a rough measure of cost of variety index can be expressed as:

$$C_v = \prod_{i=1}^{i=3} (\alpha_i) \quad (4)$$

where $\alpha_i$ denotes a mapped parameter for an *i*th cost factor.

**Current value of an *i*th factor**

In the case of cost of variety, the above factors were also considered relevant by Ishii *et al.* (1995). The cost factors – number of options, time measured from finished stage, and change-over efforts – are parameters corresponding to a current value of the *i*th cost factor. The current value of an *i*th factor is governed by the following parametric equation:

Current value for an *i*th cost factor = (minimum value for the *i*th cost factor) $(1 - \alpha_i)$ + (maximum-value for the *i*th cost factor) $(\alpha_i)$ (5)

The current value of a cost factor is mapped into these parameters, $\alpha_i$, in such a way that that if $\alpha_i$ equals zero, the current value is the minimum value of the cost factor and if $\alpha_i$ equals 1, it reaches its maximum value. The parameters $\alpha_i$ , thus, takes a value between 0 and 1 as follows:

where $0 \le \alpha_i \le 1$ ; $i$ =1, 3 (6)

The term $\alpha_i$ indicates the factors in Equations 4 and 5. *Cv* is smaller if either number of options are large, or the stage in manufacturing is early or the efforts required to change over takes more time. The actual cost of variety for producing a part with specifications $\alpha_1$, $\alpha_2$, and $\alpha_3$, can be computed as follows:

Cost of variety = minimum cost of manufacturing an assembly * $(1-C_v)$ + maximum cost of manufacturing an assembly * $C_v$ (7)

where $C_v$ is given by Equation (4).

**Design for variety**

Design for variety (DFV) is normally associated with minimizing the cost of providing a set of variety options. Design for lowest cost is, however, irrelevant since lowest cost is achieved when variety = 1. It is therefore more desirable to include other value characteristics in addition to cost in "designing for variety."

### Right amount of decomposition

Interactions among the various sets lead to a set of desirable behaviors, but they also produce a set of undesirable characteristics or behaviors that need to be controlled. This leads to the imposition of a set of necessary constraints on each design. Such constraint impositions are essential to control any adverse design outcome and to ensure a sound economical solution corresponding to some good CE manufacturing practices. The finer are the decomposed tasks, the less complex it is to solve each, because the corresponding sets of specifications for solving each of these smaller sets are smaller. However, the amount of effort required for managing the information resulting from decomposed parts increases proportionally. A large number of tasks require an equally large number of teams or work-groups to solve them. Depending upon the teams and the teams' interdependencies, there will be an equal number of interfaces. The greater the interdependence between components, the greater will be the need for communication and co-operation between them (Deming, 1993). It is shown, in Figure 5, that if there are $n$ decomposed tasks, the communication effort for the decomposed set is proportional to:

$$\text{Communication effort} \propto [n * (n - 1)/2\ ] \qquad (8)$$

where, $n$ is the number of communication nodes.

#### Level of communication efforts required

Figure 6 shows the variation of the product or process complexity and the corresponding level of communication efforts required. As shown, there is a particular level of granularity in the decomposed parts that provides an optimal balance. When the level of decomposition reaches this optimal level, the effort of communication is manageable and, at the same time, the level

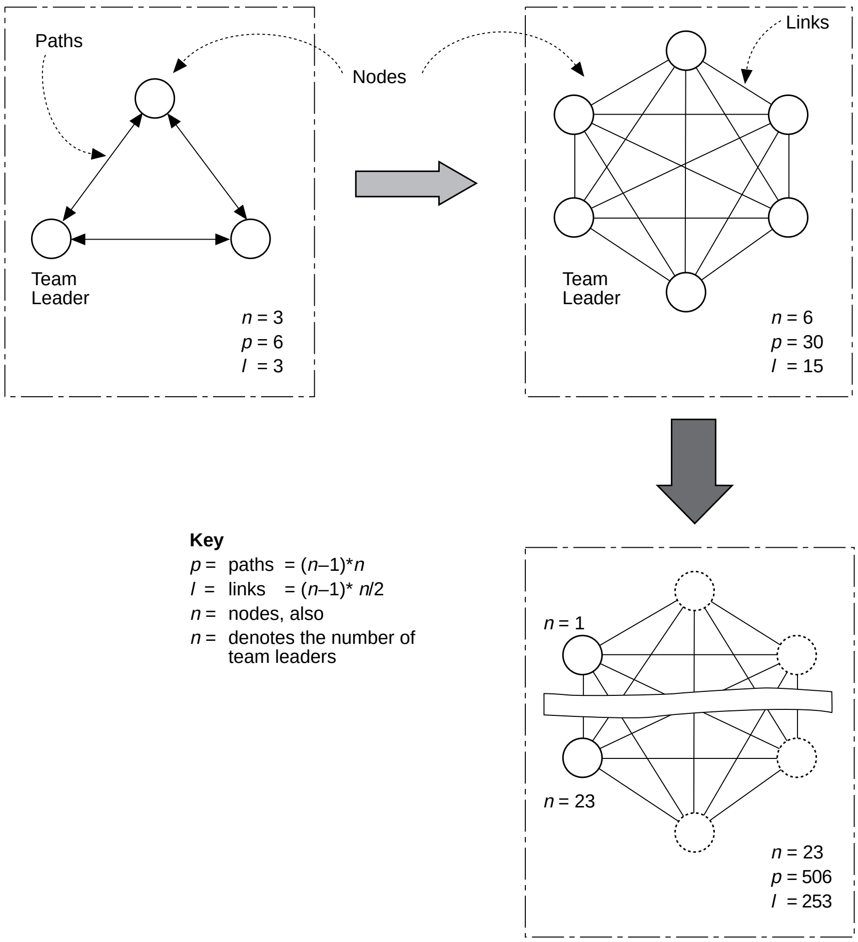


*Figure 5. Growth in communication paths in a matrix organization*

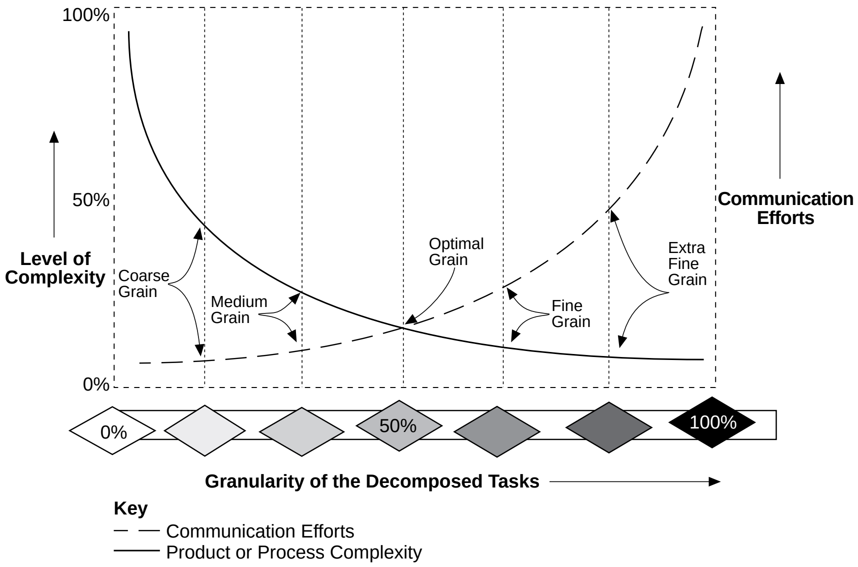


*Figure 6. Right amount of decomposition to manage both the complexity and the communication efforts*

of complexity is also reduced. Additional means, such as an interval for time dependencies, impact analysis, risk assessment, knowledge processing, and neural techniques, can predict unknown domains and ease the communication burden. If the optimal grain falls at 50 percent granularity point, and if 10 percent deviation from this point is considered acceptable, the relative increase in the complexity and the amount of efforts both remain under control. As shown in Figure 6, they tend to stay within a 10 percent range. The above is based on the assumptions that other parameters are constant and not perturbed. However, the right amount of decomposition may depend upon additional factors other than communication efforts, such as additional criteria employed in evaluation, production tasks, organizational factors (types of company, corporate culture, investment strategy, management style, etc.)

## Concluding remarks

**Breakdown structures**

It is the complexity of the products and of the processes present in the system (such an automobile) which compels a product manufacturer to look for their (products and processes) breakdown structures. This breakdown is necessary to exploit any inherent concurrency so that the individual tasks can be overlapped (run in parallel). The breakdown of structures also facilitates a reduction in the level of abstraction and tasks' dependency. The greater the number of tasks in the decomposed set, the greater will be the need for communication and co-operation between the teams performing those tasks. The paper described a mechanism to measure granularity in the decomposed tasks and to manage both the complexity and the communication efforts simultaneously. The paper described how to manage complexity so that communication efforts stay within an acceptable range and volume-related costs are minimized.

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***This summary has been provided to allow managers and executives a rapid appreciation of the content of this article. Those with a particular interest in the topic covered may then read the article* in toto *to take advantage of the more comprehensive description of the research undertaken and its results to get the full benefit of the material present***

## Executive summary and implications for managers and executives

***Managing complex products or how to eat an elephant (one bite at a time)***

*It's been said (I forget by whom) that the way to achieve an impossible task is to break down that task first into the nearly impossible, then to the extremely difficult and so on until you have a series of simple tasks that, taken together, deliver the impossible. Now, it's also true that this tongue-in-cheek approach sums up the operational management issues facing firms manufacturing complicated technical products, especially when the product is designed for variety.*

*There's nothing new about the concept of breaking up a complex process into easy tasks so as to make it achievable. Indeed, the concept of the production line derives from this observation. But when there are parallel processes occurring, to differing time scales and at geographically diverse locations, the situation becomes still more involved.*

*Prasad describes the situation at a car manufacturer where manufacturing engineers work on the current model, process engineers on next year's model and product engineers on the model for two years hence (I admit my version's a little bit of a simplification but it makes the point). At the same time, groups serving these processes must chop and change between the needs of current production, the advanced stages of the next year's production and the concepts of some future vehicle.*

*Add to this the likelihood that the current year's production isn't of just one vehicle option but dozens of variations. So, before our heads explode just thinking about this nightmare of complexity, it's good to know that such systems can be managed effectively provided that we think about what we're doing and develop effective systems to ensure adequate communications between the different elements in the production process.*

*Prasad presents us with a series of decisions about this process that need answering in order to create the system most able to cope with:*

- *the requirements of production and product development time scale;*
- *the need to contain costs; and*
- *maintaining control of the process.*

*These questions can be couched in engineering terms or (for those of us less able to cope with such terms) as follows:*

- *How small should we make the pieces of elephant?*
  *The smaller the piece, the easier to swallow but the longer it takes to eat the beast. Prasad terms this the right amount of decomposition, pointing out that the amount of effort required is defined as the square of the number of tasks involved. It may be lots of little and easy tasks but it takes a great deal more effort.*
- *How big a team do we need to eat the elephant?*
  *With more people we will finish more quickly but this raises the problem of maintaining communications between those involved and implies adding to the costs of the project. There is a conflict between the desire to get the product to market as fast as possible and the costs of achieving that task. An efficient system counters this conflict by allowing fewer people to eat more mouthfuls of elephant.*

*Moving away from our elephant allegory we need now to look at two other issues:*

*(1) running parallel processes; and*

*(2) incorporating product variety.*

***Parallel processes***

*We've noted that the manufacturer of complex technical products isn't simply making them. At the same time as manufacturing for current market demand the firm has to plan for future production and develop the next generation of products. Prasad notes that modern industry now delivers new products more quickly than ever before. The car manufacturer can no longer afford five years to develop the next car – three years appears to me to be the longest allowable time. And for manufacturers of computers and related high technology equipment the time to market needs to be shorter still.*

***Product variety***

*The new product isn't just one simple product. The chances are the new car will come in several different engine sizes, a diesel and petrol engine version, a hatchback and saloon, a sporty version and today's multitude of paint and trim finishes. Not only does this product variation add complexity but also it adds costs. Decisions need to be made regarding the amount of "pain" acceptable in producing variations but the numbers and types of variation proposed. And the stage at which the variation is added, its effect on the price and the impact of variation on the overall product development process all make a difference to decisions about variety.*

*Prasad argues that focusing on cost leads us to the decision that only one version should be built since that is the logical answer to a question such as "what's the cheapest way we can do this?". Instead, we need to decide – ahead of the cost question – what variations are needed to satisfy likely market demand. Only then can we ask about how to deliver such needs at the lowest possible cost.*

*Similarly we need to establish when we want the project finished. Time to market matters as much as cost so, since it's more expensive to develop products quickly, we need to set the time scales before establishing the cost basis.*

*At the end of the day, Prasad's assertion is that these complex processes cannot be achieved without sophisticated communications and information technology. Everyone in the production and product development process needs to appreciate just where they fit in, what other areas are doing and where difficulties or problems occur. Without such a system, you simply won't mange to compete in a technically complex market.*

(A précis of the article "Designing products for variety and how to manage complexity". Supplied by Marketing Consultants for MCB University Press.)