

# ***A CONCURRENT APPROACH TO NEW PRODUCT DEVELOPEMNT***

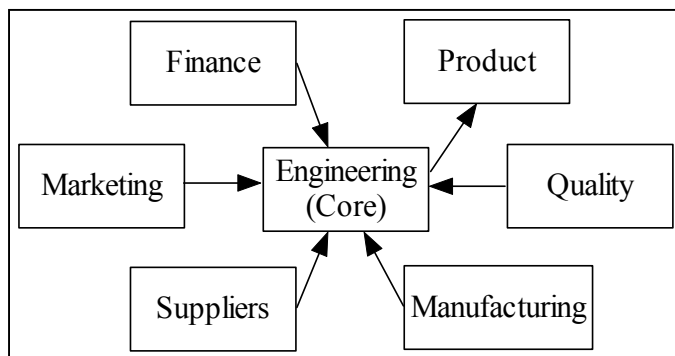
BY STEVE MOWRY

The term concurrent is defined as running parallel; operating at the same time; and/or acting in conjunction. We can apply this concept to the product development process. Let's investigate the implementation and documentation of concurrent product development and the related concurrent project management.

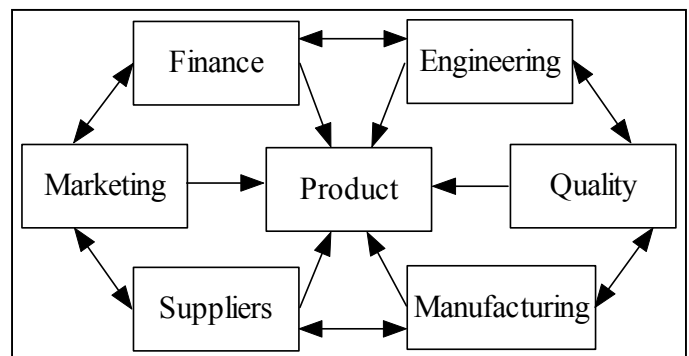
Concurrent product development (CPD) has two fundamental components.

1. Concurrent Engineering (CE) is a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. This approach is intended to cause the developer, from the outset, to consider all elements of the product lifecycle from concept through disposal, including quality control, cost, scheduling and user requirements.
2. Integrated Product Development (IPD) is a philosophy that systematically employs a teaming of functional disciplines to integrate and concurrently apply all necessary processes to produce an effective and efficient product that satisfies the customers' needs.

Let's take a look at two product development functional resource models.



**Engineering 'Owns' the Project.**



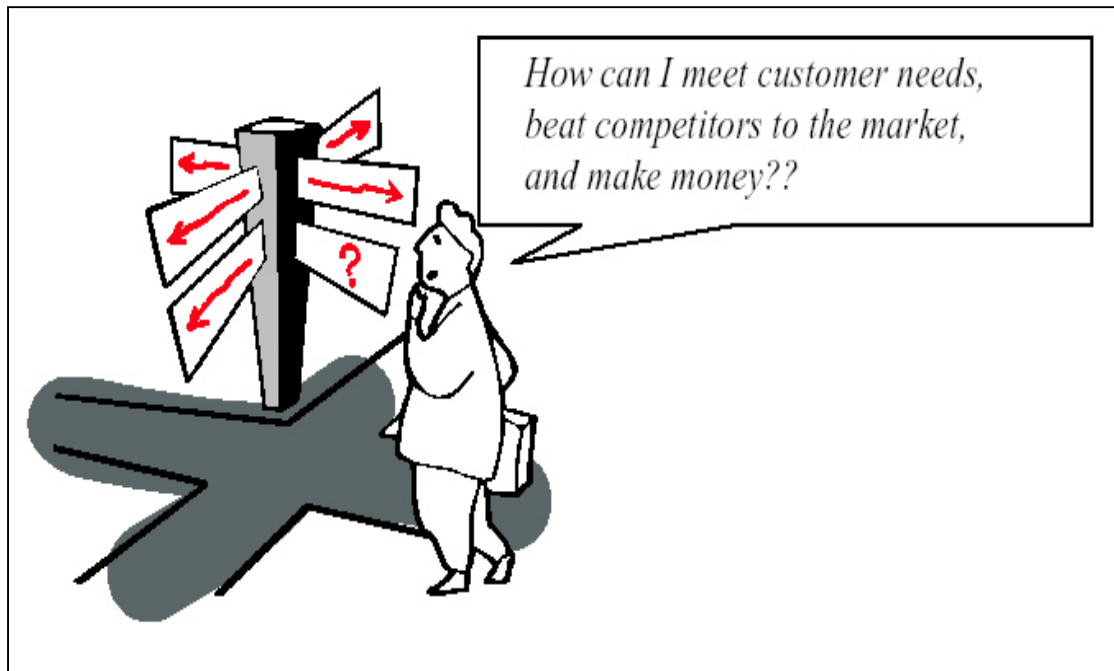
**Everyone Together 'Owns' the Project.**

What are the likely consequences of these two models?

1. Functional silos
2. Functional views
3. The buck stops with Engineering
4. Heavily serial activities
5. Late, costly, and/or failing to meet customer needs

1. Cross-functional input from start
2. Holistic view of development
3. The buck stops with the Team
4. Parallel activities
5. On time, within budget, and customers delighted

## THE CHALLENGE OF CHEAPER, FASTER AND BETTER CAN BE MET.



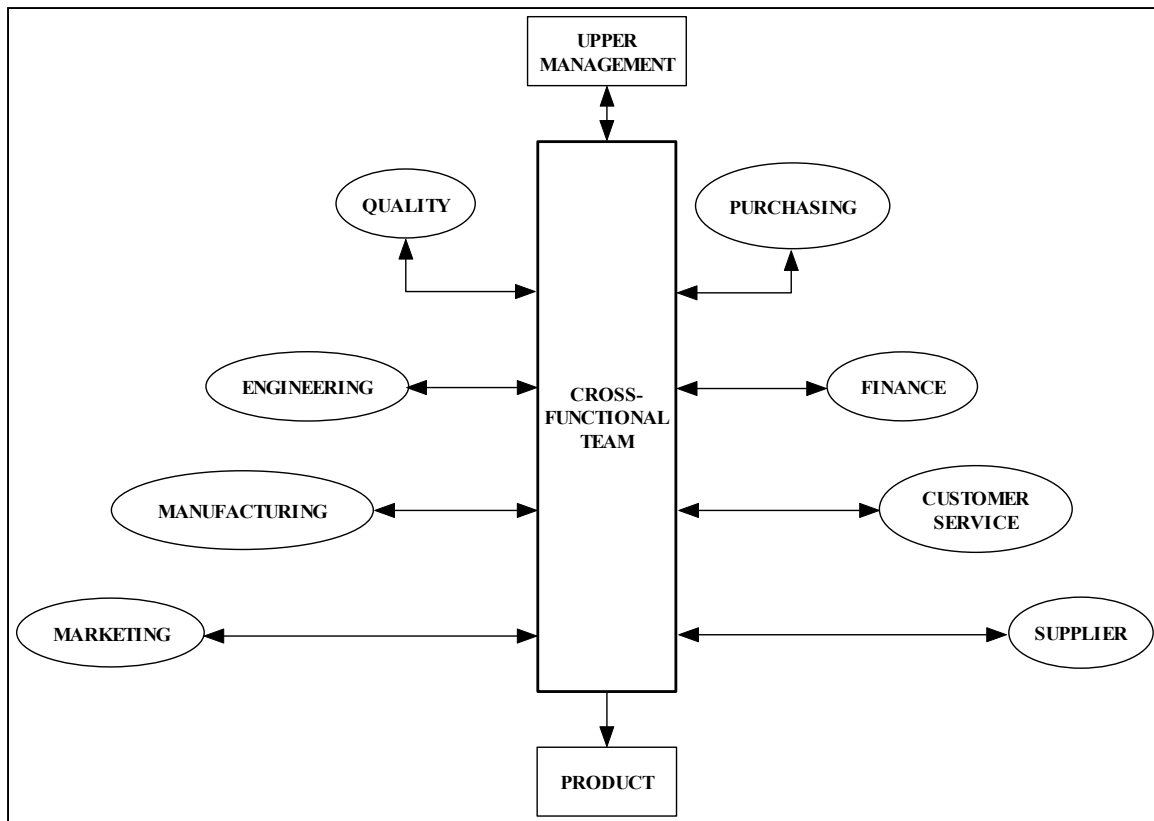
### **Concurrent Product Development is the only way to get all three.**

**CPD** works with all sizes and types of companies. This has been proven over and over by several case studies in Europe and the USA, including CEPRA, PASE, the Society of Concurrent Product Development (**SCPD**), and the Quality Function Deployment (**QFD**) Institute. Benefits of **CPD** include 30% to 70% less development time, 65% to 90% fewer engineering changes, 20% to 90% less time to market, 200% to 600% higher quality, and 20% to 110% higher white-collar productivity. There is no checklist for implementing **CPD** because there is no one solution. Each application will be unique.

Let's remember that strategy, people, process, tools, technology, and costs are essential elements of the business plans for all companies. However, it is critical for us to plan and utilize these elements, resources, in the most efficient and effective manner.

Now we must form the cross-functional product development team. The cross-functional team should consist of 6 - 8 members. Let's look at a diagram of a typical cross-functional team.

## THE HIERARCHY OF THE CROSS-FUNCTIONAL TEAM



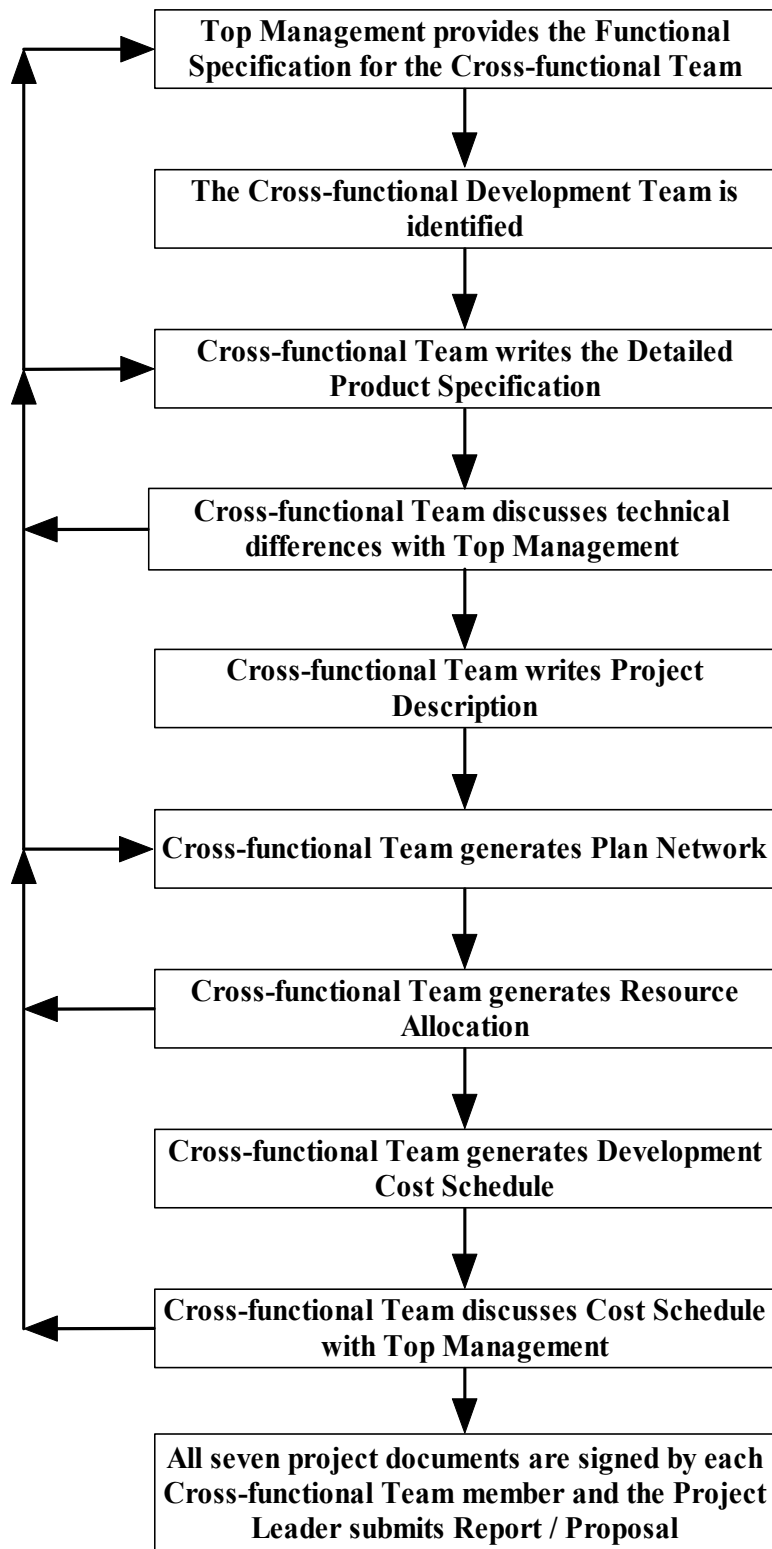
Notice that the hierarchy of the cross-functional team is ‘top down’ with everyone working together. The cross-functional team is an entity with accountability; however, no finger pointing please.

Now let’s take a look at the seven steps of the top down flow of project documentation.

1. Top management supplies the **Functional Specification**.
2. The cross-functional team supplies the **Detailed Product Specification**.
3. The cross-functional team supplies the **Project Description**.
4. The cross-functional team supplies the **Plan Network**.
5. The cross-functional team supplies the **Resource Allocation**.
6. The cross-functional team supplies the **Cost Schedule**.
7. The project leader or champion supplies the **Report / Proposal**.

We can better illustrate the project documentation procedures and flow through the use of a flowchart.

## THE FLOWCHART OF CONCURRENT PROJECT PLANNING



A crucial element of any project is the project documentation. We shall briefly describe each element of the project documentation.

## THE FUNCTIONAL SPECIFICATION:

A written description of the product to be developed as it is viewed from the top level down. Typically the functional specification is presented to the cross-functional team from a higher supervisory level. This document should describes the functional characteristics of the product to be developed including the performance expectations and a cost target.

## THE DETAILED PRODUCT SPECIFICATION:

A complete physical description of the product to be developed that is written by the cross-functional team. The detailed product specification must conform to the Functional Specification. The cross-functional team should study competitive products and customer needs. Brainstorming and creativity can be performed in a group setting that could potentially increase motivation and enthusiasm.

## THE PROJECT DESCRIPTION:

The first two documents of the project plan, the functional specification and detailed product specification, describe the product. The cross-functional team has fully described the system to be developed. The team 'owns' the project. The project description is a brief description of the project, typically inclusive of the project objectives that are written by the cross-functional team. Finalizing or 'hardening' the specifications is a prerequisite for writing the project description, 'design-it-once' criteria. Without hardening specifications early on in the project, the product is typically designed 5 times!

## THE PLAN NETWORK:

Your project plan should be based on previous experiences and sound mathematics. Additionally, project documentation provides valuable management information that facilitates setting goals for future improvement and establishes benchmarks for future development project procedures. Let's look at some simple examples of worksheets and graphs that we can use to help manage the development project.

A table is shown below that allows use to list each project task; the person whom is to perform the task; and three time estimates. Additionally there is an initials column for each team member to sign as a symbol of concurrence. Please don't worry, this is not a contact; however, it does set a standard for accountability. The worksheet shown below can be easily implemented with any spreadsheet computer program such as MS EXCEL.

## ACTIVITY WORKSHEET TEMPLATE

No.	Activity	Person(s)	t <sub>m</sub>	t <sub>o</sub>	t <sub>p</sub>	t <sub>e</sub>	σ <sub>e</sub> <sup>2</sup>	Initials
1-2								
1-3								
2-6								
3-4								
3-11								
4-5								
5-13								
6-7								
6-8								
7-9								
8-10								
9-14								
10-15								
11-12								
12-13								
13-15								
14-17								
15-16								
16-18								
17-18								
18-19								
...								

**t<sub>m</sub>** is the most likely time for previous similar activities.

**t<sub>o</sub>** is the optimistic time for previous similar activities at a ~5 % probability.

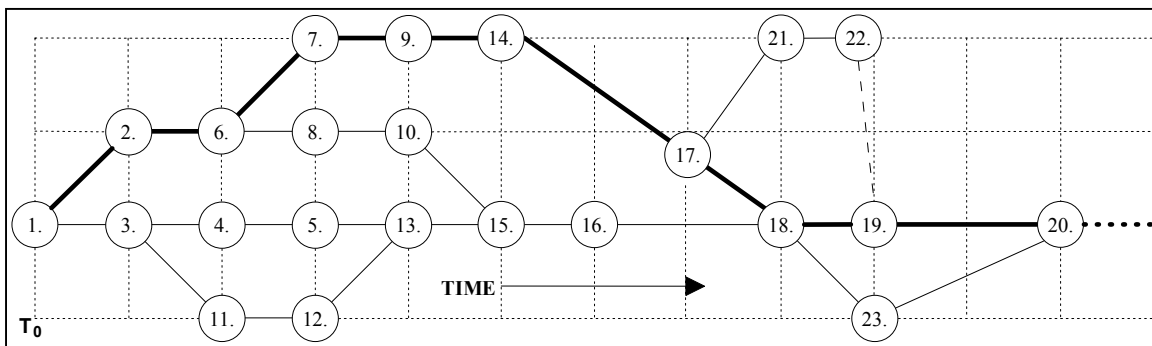
**t<sub>p</sub>** is the pessimistic time for previous similar activities at a ~95 % probability.

**t<sub>e</sub>** = (t<sub>o</sub> + 4t<sub>m</sub> + t<sub>p</sub>) / 6 is the expected activity time at a 50% probability, with a variance, σ<sub>e</sub><sup>2</sup>.

σ<sub>e</sub> = (t<sub>p</sub> - t<sub>o</sub>) / 6 is the standard deviation.

Each project plan should contain no less than 50 activities to effectively apply the Central Limit Theorem. The Central Limit Theorem essentially states that if the sample size is large, then all processes are normally distributed.

### PLAN NETWORK SEGMENT EXAMPLE



**The ‘Critical Path’ is the longest time path, shown in bold.**

The plan network is a graphical representation of the data we collected while filling in the activity worksheet. The line between numbered circles indicates the activity. This relates to the data contained within the first column of the activity worksheet.

$$T_E = t_{e_{1-2}} + t_{e_{2-6}} + t_{e_{6-7}} + t_{e_{7-9}} + t_{e_{9-14}} + t_{e_{14-17}} + t_{e_{17-18}} + t_{e_{18-19}} + t_{e_{19-20}} + \dots$$

The probability of 'On-Time Completion' is only 50% for time  $T_E$ , the sum of activity time along the critical path. The risk is too high. Let's include critical activity variance in the planning.

$$\sigma_E = \sqrt{\sigma_{e_{1-2}}^2 + \sigma_{e_{2-6}}^2 + \sigma_{e_{6-7}}^2 + \sigma_{e_{7-9}}^2 + \sigma_{e_{9-14}}^2 + \sigma_{e_{14-17}}^2 + \sigma_{e_{17-18}}^2 + \sigma_{e_{18-19}}^2 + \sigma_{e_{19-20}}^2 + \dots}$$

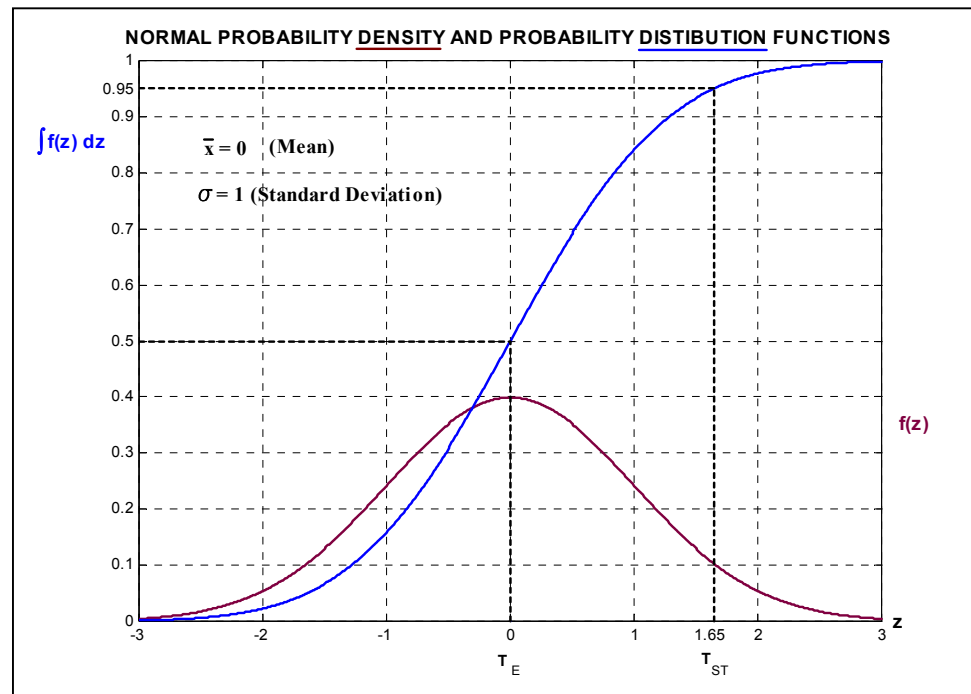
$\sigma_E$  is the project standard deviation, which is the square root of the sum of the critical task variances .

Let's examine the normal probability density and distribution functions respectively on the left below.

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{-z^2/2}$$

$$z = \frac{x - \bar{x}}{\sigma}$$

$$\int_{-\infty}^{1.65} f(z) dz = 0.95$$



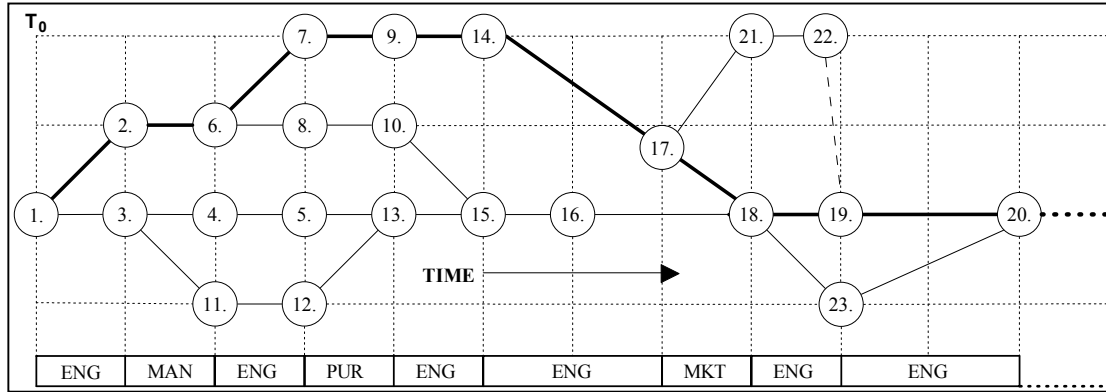
$$T_{ST} = T_E + 1.65\sigma_E$$

The probability of on time completion is now 95%, for time,  $T_{ST}$ !

#### THE RESOURCE ALLOCATION:

Assign the appropriate talents to the corresponding project activities. Obtain approval for human resources from the source managers for scheduled allocations. Modify the Plan Network if necessary. Draw the Resource Allocation in the form of a histogram or vertical bar chart on the same time scale as the Plan Network. Also draw separate histograms for critical and non-critical human resource allocations. All members of the cross-functional team must agree on the resource allocation. Careful resource allocation helps to prevent schedule slippage.

## PLAN NETWORK SEGMENT WITH CRITICAL HUMAN RESOURCE ALLOCATION



## OTHER HUMAN RESOURCE ALLOCATION

			QC		MAN								
		ENG	PUR	S	ENG	PUR			ENG	PUR			
CS	S	MKT	SUP	S	SUP	SUP	MAN	S	SUP	SUP	FIN	S	

S = Slack Time

**Without sound planning and realistic scheduling before the project begins, it is impossible to achieve good control of the project later on.**

### THE COST SCHEDULE:

Your project cost schedule should also be based on previous experiences and sound mathematics. We start by filling in the cost work sheet. This document contains the previously listed activities from the activity worksheet, the number of people required to perform the activity, and the unit cost of each person listed. The total cost is then simply the product of the number of people, number of days and the costs per day. We can then plot the data from the worksheet as a function of time and compare the curves to the resource allocations.



## THE PROJECT REPORT/PROPOSAL:

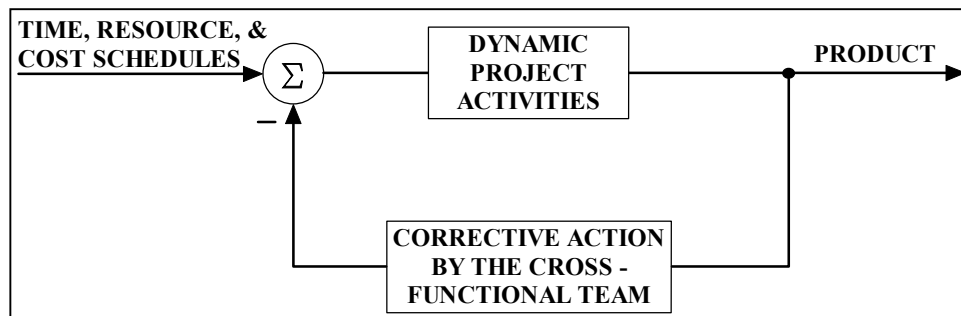
A request for approval of the development project from upper management and is a request for project funding. This document should consist of two parts, an executive summary that contains no more than 200 words and the back-up documentation that gives credibility to this summary. The project leader or project champion should write the project report/proposal. This is typically the Project Engineer. All cross-functional team members must 'sign-off' on all project planning and costing documentation as a symbol of concurrence. The project leader presents this proposal to upper management. Top managers must decide which projects to pursue. To do this effectively, they need realistic time, resource, and cost schedules.

**We have our project planning and scheduling documentation, now let's investigate some powerful product development tools and methodology.**

## CONCURRENT PROJECT CONTROL:

Concurrent project management requires closed-loop feedback control. Use the same documentation templates generated during the planning and scheduling phases for reporting the progress and cost of the project to date to upper management. The cross-functional team needs to know the current status of the project to effectively control it. The team should meet weekly for at least one-hour for the purpose of discussing the project status and upper management should be kept informed as to the project status.

### A PROJECT MANAGEMENT CONTROL SYSTEM



## PROJECT COST MANAGEMENT:

The process of placing responsibility on the project designers, facilitators, and implementers to perform within their previously established budgets.

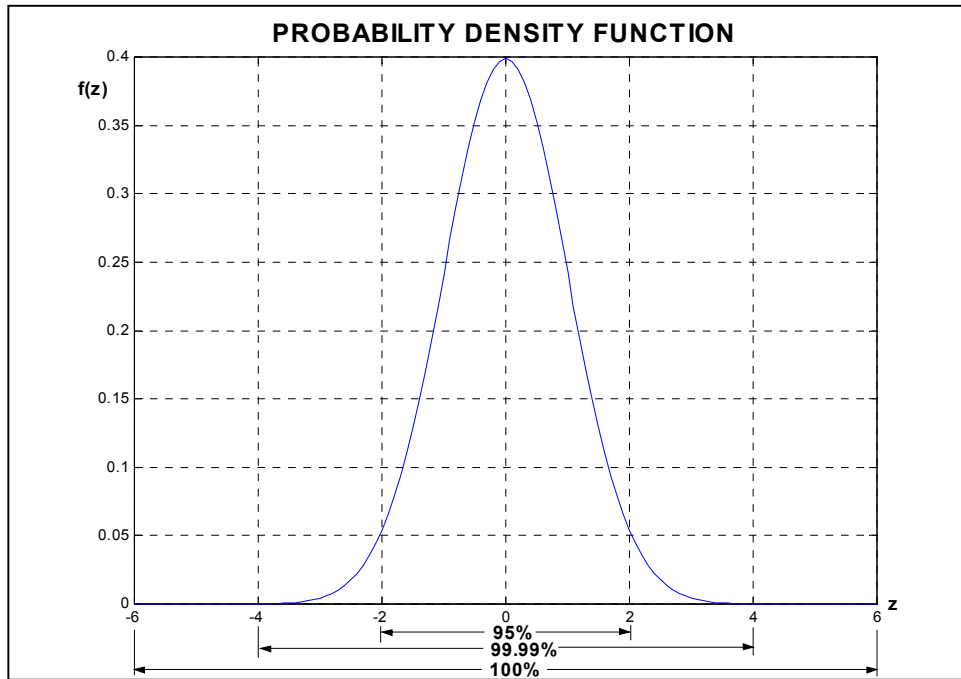
1. Proactive development cost management by the cross-functional team is crucial, only future costs can be controlled.
2. Establish a target-costing program (**Cost Function**).
3. Target cost and '**Design to Cost**'.
4. Supplier roles in '**Design to Cost**'.

5. Understand the cost drivers.
6. Perform make-buy analysis.
7. Analyze relationships between product costs, development costs, and production volume.

ELEMENTS OF DESIGN FOR FOUR TO SIX-SIGMA PRODUCTION:

1. Concurrent Engineering (CE)
2. Design for Manufacturability, Assembly and Reliability (DFMAR)
3. Failure Mode and Effect Analysis (FMEA)
4. Quality Function Deployment (QFD)
5. Robust design and processes (DOE)

$\int_{-2}^2 f(z) dz = 0.9545$       The equations on the right represent the respective acceptance rates for 2, 4 and 6-sigma production. Let's look at a graphical representation of the normal probability density function,  $f(z)$  versus sigma, the standard deviation.  
 $\int_{-4}^4 f(z) dz = 0.9999$   
 $\int_{-6}^6 f(z) dz \approx 1.0000$



**Six-sigma is almost the Zero Defect Product!**

We have defined and discussed concurrent engineering. Now let's look at the other elements of four to six-sigma production.

## DESIGN FOR MANUFACTURABILITY, ASSEMBLY AND RELIABILITY:

Let's look at a simple equation that can make life much simpler for the development team.

**Number of part types =  $N_t$**

**Number of parts =  $N_p$**

**Number of interfaces =  $N_i$**

**Complexity Factor =  $\sqrt{N_t + N_p + N_i}$**

The complexity factor should be minimized and please don't forget to keep the number of fasteners to a minimum. We can itemize a summary of this design methodology that can be used as a design checklist by the team.

1. Simplify the design and reduce the number of parts.
2. Standardize and use common parts and materials.
3. Design for ease of part fabrication.
4. Design within manufacturing process capabilities.
5. Avoid unneeded surface finishes.
6. Mistake-proof product assembly whenever possible.
7. Design to minimize parts orientation and handling.
8. Design for ease of assembly.
9. Design for efficient joining and fastening.
10. Design modular products and product families.

## FAILURE MODE EFFECT ANALYSIS (FMEA):

A powerful tool that encourages the development team to anticipate problems and issues before they can negatively impact the project / product. We shall summarize this tool below.

1. Develop product and /or processes that minimize the likelihood of failures, '**Design for Reliability**'.
2. Evaluate the requirements obtained from the customer and other participants in the design process to ensure that those requirements do not introduce failures.
3. Identify design characteristics that contribute to failures and design them out of the design or at least minimize the resulting effects (Design Rules).
4. Develop methods and procedures to test the product and processes to ensure that the failures have been successfully eliminated (Test Specification).

5. Track and manage potential risks in the design. Tracking risks contributes to the success of future products by helping to build a 'Body of Knowledge'.
6. Any failures must not seriously impact the customer.

#### FMEA WORKSHEET TEMPLATE

DESCRIPTION	FUNCTION	FAILURE MODES	EFFECT	CAUSE	CORRECTIVE ACTION	PERSON RESPONSIBLE	SEVERITY	OCCURRENCE	DETECTION
							1 to 10	1 to 10	1 to 10

Again the simple template above lends itself to a spreadsheet computer program. FMEA forces the team to consider causes of possible failures. Let's summarize the use of this tool.

1. Use FMEA for both product and process design.
2. Rate the severity of failure modes.
3. Identify corrective action to reduce occurrence.
4. Test adequacy of the controls' capability to detect.
5. RPN is the risk priority number, the lower the better.
6.  $RPN = Severity \times Occurrence \times Detection$

#### QUALITY FUNCTION DEPLOYMENT (QFD):

A company wide philosophy, that will help assure the success of the product to be developed. A summary of the methods of **QFD** is listed below.

1. Links the needs of the customer and the end user with design, development, engineering, manufacturing, and service functions.
2. Helps organizations seek out both spoken and unspoken customer needs, translating these into actions and designs.
3. Assess customer affordability.
4. Obtain customer feedback on requirements.
5. Focus on customer needs.
6. Perform functionality versus affordability analysis.
7. Use **QFD** to help manage requirements and costs.

## DESIGN OF EXPERIMENTS (DOE):

Another powerful tool for the development team and is the most efficient approach to experimentation. **DOE** can identify interactions between and among variables. With **DOE** you can quickly optimize the manufacturing processes; however, the mechanics of **DOE** are beyond the scope of this article. Let's save statistical process control (**SPC**) and design of experiments for a subsequent article topic; however, these are important elements in our quest for zero product defects.

The good news is that there is relatively easy to use software available that will simplify and facilitate meaningful use of **DOE** or you can implement the template shown with a spreadsheet computer program. Let's list the formulae that are required to perform simple but extremely powerful experiments.

1.  $\bar{y} = \frac{y_1 + y_2}{2}$  the mean.
2.  $R = |y_2 - y_1|$  the range.
3.  $SUM_+ = \sum y(+)$  the sum of values in the + boxes.
4.  $SUM_- = \sum y(-)$  the sum of values in the - boxes.
5. **Difference** =  $SUM_+ - SUM_-$
6. **Effect** =  $\frac{\text{Difference}}{\text{Number of + signs}}$  a sanity check.
7.  $F = \left( \frac{\sum R_+}{\sum R_-} \right)^2$  the variability factor.
8.  $\sigma' = \frac{\sum R_+}{\text{Number of runs} \times d_2}$  the standard deviation of the experiment.
9.  $\sigma'_{\text{effect}} = \sigma' \sqrt{\frac{4}{N}}$  the standard deviation of the Effect.
10. **CL** =  $\pm t\sigma'_{\text{effect}}$  the experiment control limits.

## DESIGN OF EXPERIMENT TEMPLATE

<b>8-Run Plackett-Burman Screening Design with 2 Replicates, <math>y_1</math> and <math>y_2</math></b>											
Treatment Combination	A	B	C	D	E	F	G	$y_1$	$y_2$	$\bar{y}$	R
1	+	+	+	-	+	-	-				
2	-	+	+	+	-	+	-				
3	-	-	+	+	+	-	+				
4	+	-	-	+	+	+	-				
5	-	+	-	-	+	+	+				
6	+	-	+	-	-	+	+				
7	+	+	-	+	-	-	+				
8	-	-	-	-	-	-	-				
SUM <sub>+</sub>								<b>N = 16</b> <b><math>d_2 = 1.13</math></b> <b>t = 2</b> <b><math>UCL_F = 6.39</math></b>  <b>Significant Factors?</b> <input type="radio"/> <b>Affecting</b> <input type="radio"/> <b>Performance:</b> <input type="radio"/> <b>Affecting</b> <input type="radio"/> <b>Consistency:</b>			
SUM <sub>-</sub>											
Difference											
Effect											
$\Sigma R_+$											
$\Sigma R_-$											
F, or if $F < 1, 1/F$											

**Use Statistical Process Control (SPC) to know your process capabilities,  
Cpk ( $\pm 3\sigma$ ) > 1.0 ?**

**Cpk = min(Cpk<sub>u</sub>, Cpk<sub>l</sub>)** the process capability index.

$$Cpk_u = \frac{\text{Upper spec limit} - \bar{X}}{3\sigma} \quad \text{where } \bar{X} \text{ is the test samples' mean.}$$

$$Cpk_l = \frac{\bar{X} - \text{Lower spec limit}}{3\sigma}$$

$$\sigma = \frac{\bar{R}}{d_2} \quad \text{the standard deviation of the process.}$$

**CONCLUSION:**

This systematic concurrent approach to product development utilizes simplified project planning / scheduling documentation and powerful project management tools and methodology. These procedures must be tailored to the specific company/project. However, it has been shown that we can keep the documentation and the project management tools quite simple.

Sound concurrent planning and budgeting are essential to the success of any new product development project. We cannot use Statistical Process Control and supervision of artesians labor alone to control quality. Without **‘Designing in Quality’**, no amount of process and/or procedure monitoring will result in four to six-sigma production. Quality is defined as the absence

of variation about a quantitative target value and is the result of teamwork that starts at the project concept stage of development.

Finally, testing and monitoring are ‘necessary evils’ and are fundamentally important in all functions, but please remember that there is no value added by testing. Can we design and develop a product such that testing is not necessary? Not without a concurrent approach. Our products are fairly simple systems. There are systems being manufactured that are extremely complex and six-sigma production is being realized.

Steve Mowry

[steve@s-m-audio.com](mailto:steve@s-m-audio.com)