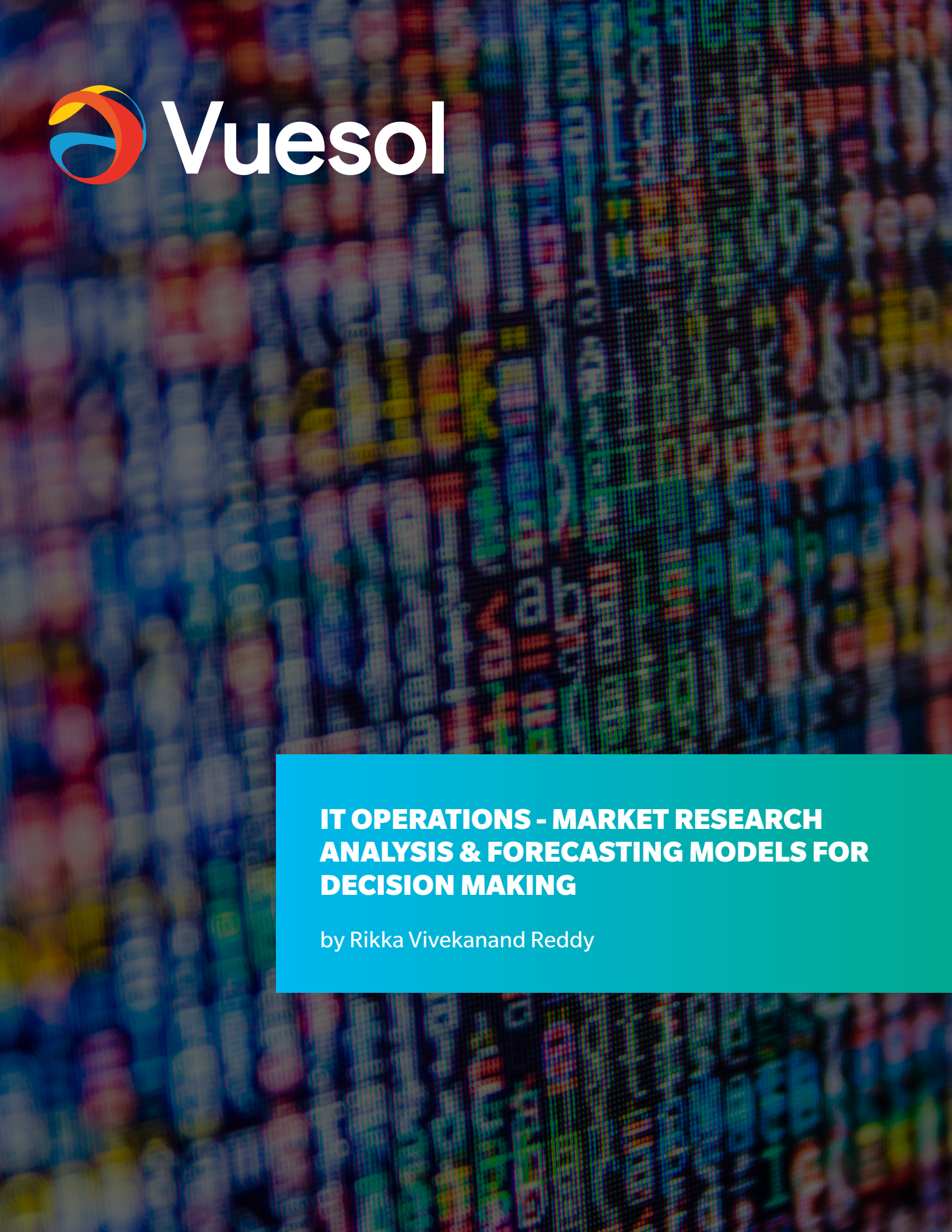


# IT OPERATIONS - MARKET RESEARCH ANALYSIS & FORECASTING MODELS FOR DECISION MAKING

by Rikka Vivekanand Reddy

## Preface of the Work

As part of my research work, I've developed this report which includes my findings for IT Operations and Supply chain. Here my findings are distributed among 3 parts of the report. The 3 parts includes the "Initial Development" followed by the "Middle Process" and the last part of it deals with the quality which is "Quality Improvement". I've used the mathematical and statistical inference to explain the concept and how it would be used in real life. Apart from it, wherever possible I've demonstrated the real time industrial example of the concepts being used in real time.

As part of the initial development, the Manager needs to know how to create a product/process followed by a forecasting and demand management for that product/process. To effectively coordinate all of the inputs from the various functional contributors to innovation process located across the supply chain, a firm has to have a strong overarching innovation strategy, as well as operational competencies in the areas of idea development, project selection , project management and organizational learning. All Operation planning activities start with some estimate of what the customer demand will be. In order to develop demand and estimates; every company has to forecast both the quantity and timing of demand. Many companies can also influence or manage customers demand patterns through product pricing and through other means.

The second part which is the "Middle Process" deals with the Process Mapping and Analysis which is a technique for documenting activities in a detailed compact and graphic form to help managers understand processes and highlight areas for potential improvements. Next is the Sales & Operation Planning of a product and process which is a process to develop tactical plan by integrating customer- focused marketing plans for new and existing products with the operational management of the supply chain.

The last part of this volume deals with the "Quality improvement". The Quality management tools male managers and employees better problem solvers by giving them the tools and produce to measure the improvement process, to identify potential problems and to describe these problems to others. These tools can help managers determine whether processes are under control or whether they are capable of meeting certain performance specifications needed to make products acceptable to customers.

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# Index

# PART 1

## Operational Product / Process Innovation Competencies

## Operational Product / Process Innovation Competencies

To effectively coordinate all of the inputs from the various functional contributors to innovation process located across the supply chain, a firm has to have a strong overarching innovation strategy, as well as operational competencies in the areas of idea development, project selection , project management and organizational learning.

As the figure shows that one can view innovation as "funnel". While many new product and process ideas maybe initially considered, the best innovators are good at pursuing a portfolio of ideas that have high potential impacts and also fit well with the firm's strategy and capabilities.

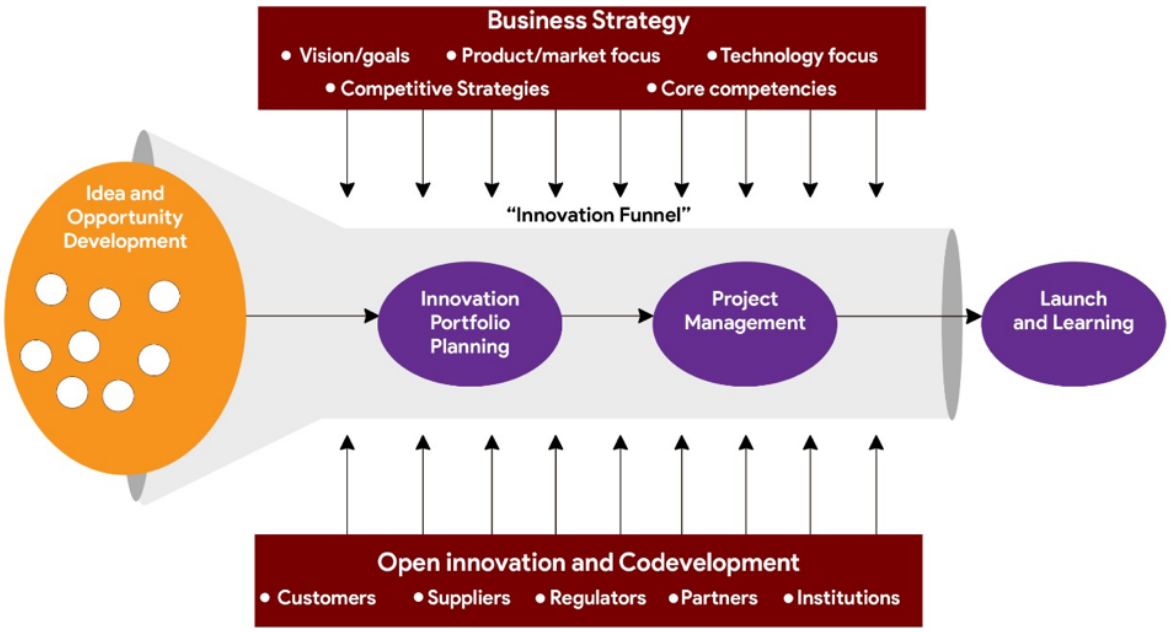



**Diagram 1.1 : Competencies for Product/Process Innovation Management**

- **Idea and opportunity development :**
    1. **Hiring the best and the brightest :** Some firms are better than others at finding and developing new ideas and opportunities for innovation . Excellent firms have a culture that motivates workers in all areas of the firm's operations to constantly be looking for new ways to improve processes and to please customers
    2. **Having an effective reward system in place :** Many firms have electronic forums or other venues where employees can submit ideas.
    3. **Allocating adequate resources :** Firms that are dedicated to innovation typically set aside a significant amount of money and worker time to the development of new ideas.

- **Innovation portfolio planning :**

  Most firms have innovation ideas than they have the resources to pursue. It is important for new ideas to be formally screened to identify those that are most promising and most consistent with the firm's business strategy and development capacity . The screening process known as innovation portfolio planning, analyzes estimated market share (by customer segment and channel), revenues, profits, investments and development time requirements.

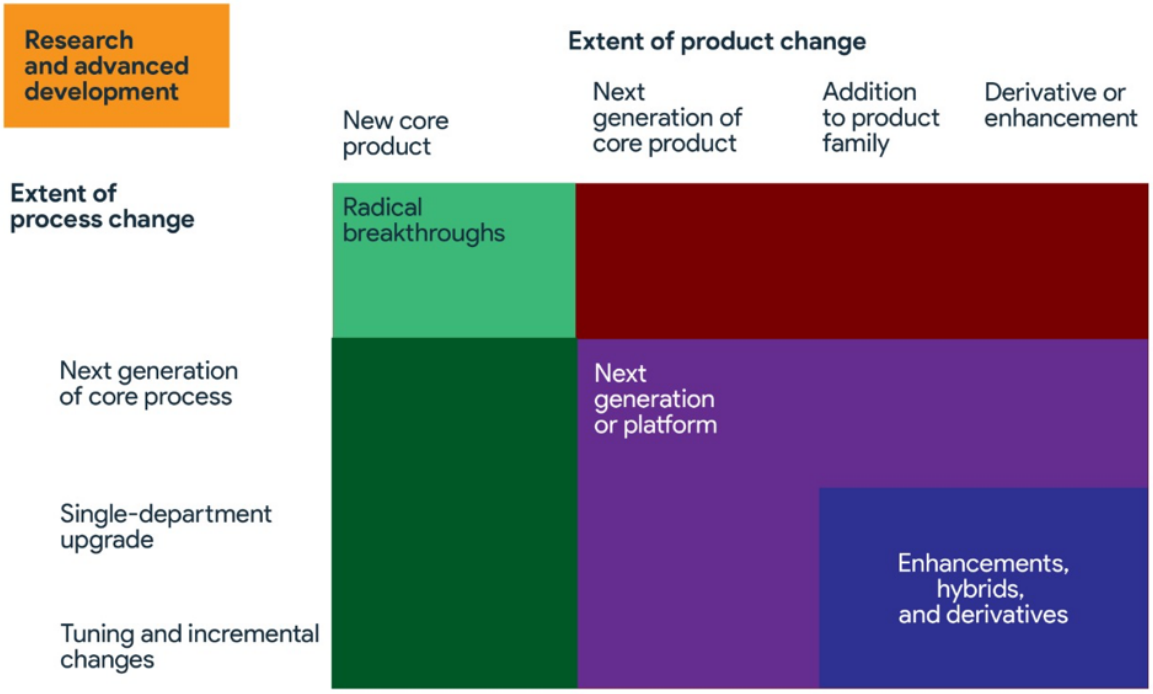



**Diagram 1.2 : Types of Development Projects**

This type of aggregate innovation planning helps establish the priority and role of every project within overall business strategy:

1. Research and advanced development projects are aimed at finding new core products or processes.
2. Radical breakthrough development projects develop products or processes that will employ some entirely new technology, perhaps one development project.
3. Next generation or platform development projects develop new product platforms using mostly existing technologies
4. Enhancements, hybrid and derivative development projects refine and improve selected features of existing products.

Operations managers can play different kinds of roles in each of these projects types. A new supplier or technology vendor may play a central role in advanced development and radical product development projects, especially if product and process technologies are highly interrelated.

## Example 1 : Procter and Gamble's Connect + Develop Process

P&G has a long and storied history of acquiring innovative ideas and technologies from outside the company. So it was no surprise when they rolled out one of the first formalized programs for soliciting and acquiring new innovations from myriad sources. P&G connect + Develop Program has established strong external relationships through the global innovation network that includes companies, individual entrepreneurs, government and contract laboratories, research institutes, suppliers and academia. The company solicits ideas for new products, packaging technologies and commercial opportunities visa the intreated based e-R&D connections (see www.innocentive.com; www.ninesigma.com; and www.yet2.com)

Procter and Gamble accelerates its internal research and development efforts by leveraging the ideas, talents and innovation assets of partners. The connect + develop approach allows them to rapidly create products to best meet the performance and costs needs of the worlds consumers. One example of the many successes yielded by this approach is Crest White Steips. P&G innovation managers worked with experts in oral hygiene, fabric and home care, and thin-film technology to develop the new product concept for crest Whitestrips.

- Innovation project management : In innovative firms, product /process design and development projects are marked by two key competencies. Discipline and flexibility
    1. A discipline innovation project has well defined process steps, consideration and inclusion of all relevant stakeholders and decision makers and well thought out metrics and incentives.
    2. A flexible innovation project includes rigorous risk analysis and contingency plans; planned evaluation and decision points where the project maybe killed redirected or continued ; and extra resources (funds, people, equipment) that can quickly redeployed.

Operations managers are usually directly responsible for planning and executing product/process innovation projects.

- **New Product/Process launch and learning :** The progression of innovation projects needs to be managed. After a new product/process is launched and brought online, it is important to capture the lessons learned from the project. A continued chain of innovation projects adds to firms overall capabilities when the knowledge gained in one project is captured and explained in next project.
- **Codevelopment :** A single firm rarely possesses all of the knowledge and resources it needs to bring the major new product to market or to bring a major new process online. Consequently, a firm often partner with other firms to codevelop the new product or process. A codevelopment relationship may involve joint ownership of the new product design or the development partnership may participate in strictly contract basis.

Codevelopment benefits include :

1. With this innovation process, the firm increases the number of sources for new and better ideas leading to higher quality products.

2. By leveraging expertise and resources of suppliers, research firms, universities and other partners companies can increase the number of products they successfully launch and reduce the time it takes to bring new products and processes online.
3. It helps companies share legal and financial risks of development.

Codevelopment risks include :

1. By including more partners, the firms risks losing control over intellectual property as there are chances of technical knowledge being compromised.
2. The firms can lose control over the goals and timing of the innovation project it becomes too dependent on partners.

## Example 2 : Co Developing with a Competitor : Clorox Aligns Its Model with P&G

Clorox acquired the Glad brand from SC Johnson. It has a strong brand, but Clorox managers soon realized that they had no technological advantage needed to create follow on products in this category. Thus, they feared that the Glad products eventually become commodities. Clorox eventually learned that scientists at Procter and Gamble were developing and market testing two important technologies: Press'n Seal and Force Flex. Both developments looked very promising, but at the time P&G lacked the financial resources needed at launch and distribute a new brand highlighting these technologies.

At first glance, this looked like attach made in heaven. P&G had innovative technologies. Clorox had an existing brand and financial wherewithal. However Clorox and P&G had also been long time competitors. Both companies saw big risks in a partnership in which P&G licensed the technologies to Clorox. Clorox could simply sit on the technologies (not use them), thus killing the potential gains from P&G. P&G could license the technologies to Clorox but withhold important information that Clorox would need in order to embed the technology into its products and manufacturing processes.

The two companies eventually agreed upon a joint venture arrangement in which both companies held a significant stake in the success of new products using the technologies. The venture has been a huge success. In fact, Clorox subsequently approached P&G for another deal in which Asian markets, where P&G has strong distribution channels and Clorox does not. This new option would never have emerged had either Clorox or P&G been unwilling to take on the risks of their initial deal. This story clearly shows how Codevelopment benefits can extend far beyond the profits associated with a single joint product development effort.

# PART 2

Demand Planning and Forecasting

## Demand Planning : An Overview

All Operation planning activities start with some estimate of what the customer demand will be. In order to develop demand. Estimates and every company has to forecast both the quantity and timing of demand and many companies can also influence or manage customers demand patterns through product pricing and through other means . The two activities demand forecasting and demand management are collectively known as demand planning

Demand planning is combined process of forecasting and managing customer demands to create a planned pattern of demand that meets the firm's operational and financial goals .

Demand forecasting is the decision process in which managers predict demand patterns whereas demand management is a proactive approach in which managers attempt to influence patterns of demand.

Demand planning effectively plans for the amount of productive capacity and other resources their business will need, both in the short term and in the long term. Demand planning also helps know what customers they should be serving and at what levels of service. It is tough to plan in advance when the demand patterns are difficult to understand.

- ### Role of Demand Planning plays in operations management

Demand planning drives almost all other activities in operations management. Managers have to anticipate demand and plan how resources need to be managed in advance of the actual demand. In order to do so the managers have to make good predictions of the various scenarios and resources they will need at a given time and place.

Accurate planning information has many benefits and there are severe costs to being wrong. The cost of making forecasts that are too high include money lost in holding inventories that are never utilized , lost capacity that is spent making products that no one wants to buy , lost wages spent paying workers who. Are not needed and so on . These costs are borne by companies in the supply chain and often passed onto the customers as well in the form of higher prices . Similarly costs of making forecasts that are too low include lost sales and lowered product availability of customers

- ### Planning activites

Forecasting activities integrate information gathered from the market , from internal operations and from the larger business environment to make predictions about the future demand . This information includes past demand, past forecasts and their associate errors , business and economic metrics and the judgements of experts.

In addition the forecasting systems uses demand management okays to specify the firms pricing strategies and promotional plans. By combining all of these factors the forecasting systems creates new forecasts of the future demand.

The demand management system in turn uses these forecasts as inputs for future demand management planning. In addition to it the forecasts and demand management plans are passed on to capacity planning and scheduling systems.

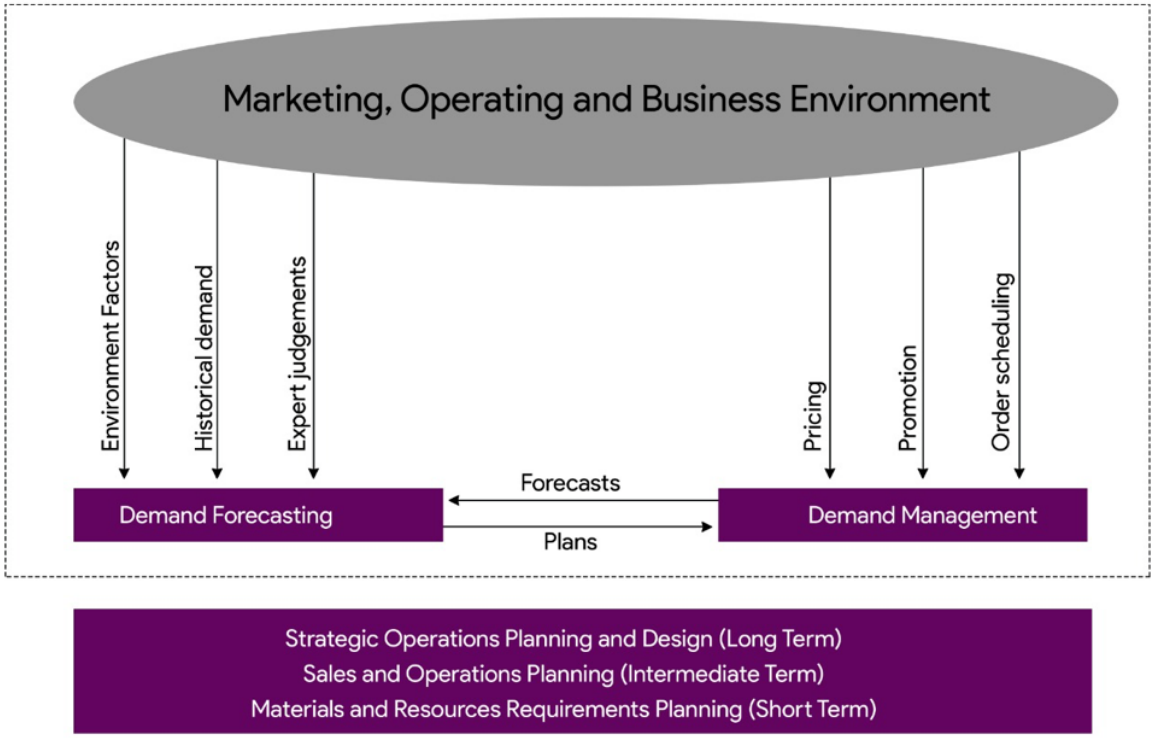



**Diagram 2.1 : Elements of Demand Planning. The image illustrates how the demand forecasting and demand management activities relate to one another and to other operational planning activities .**

| Time Horizon/ Type of Planning | Demand Planning Units | Uses of forecasts and Demand Management Plans | Types of Decisons Involved |
|---|---|---|---|
| Long Terms/Strategic 1 - 5 Years | Total Dollar or unit sales for a business unit across the sales network | • Supply Chain network design<br>• Technology Investments<br>• Capacity Planning (investments or Divestments) | • Find new sources of supply<br>• Build or sell a plant<br>• Contract for transportation services<br>• Open and close new service location |
| Intermediate term/tactical 6 - 18 months | Total dollar or unit sales for a product family in the region | • Sales and operational planning<br>• Product portfolio planning | • Aggregate production plans<br>• Employee hiring and firing<br>• Planned overtime work<br>• Subcontracting<br>• New product launches |
| Short Term/Operational materials and resources 1 - 12 weeks | Dollar or unit sales for a given time | • Inventory Planning<br>• Purchasing plans<br>• Labor Scheduling | • Daily production schedule<br>• Daily work schedule<br>• Purchase orders |

**Table 2.1 : It describes the types of demand planning that support various levels of operational planning across the supply chain.**

## Demand Forecasting

It is important to think of forecasting as a process rather than simply a technique or a model . The process should be sophisticated enough to achieve acceptable levels of forecast accuracy, but simple enough so that steps involved can be understood by the users. It is also important to improve the forecasting process to improve its accuracy , user friendliness and flexibility. It required the use of statistics and forecasting techniques consequently ensuring the end users must understand and accept the underlying logic of the system.

### Example 1 : The Tribune's Famous Fallacious Forecast

Forecasting problems are not new and not unique to any given area of business. In 1948, the chicago tribune tried to scoop its competitors by conducting a telephone survey in order to predict the outcome of the presidential election. Based on those results , the papers editors ran an election day special proclaiming "Dewey Wins". When the final count reviewed the Democrat Harry S. Turman had defeated Republican Thomas Dewey., the misfortunes experienced by the Chicago Tribune taught the world two lessons. The first is the danger of basing forecasts on inaccurate information sources . The survey's sampling plan ignored the bias introduced by telephone polling - more republicans than democrats owned telephones. The second and more important lesson was that it is always important to consider the consequences for forecast errors. Since perfect forecasts don't exist, one should always consider the cost of being wrong.

- ### Components of Demand

Most of the forecasting techniques seek to uncover patterns in demand and to extrapolate them to future. The forecasting objective is to uncover and describe the time series pattern . The demand pattern is made up of different component processes that work together.

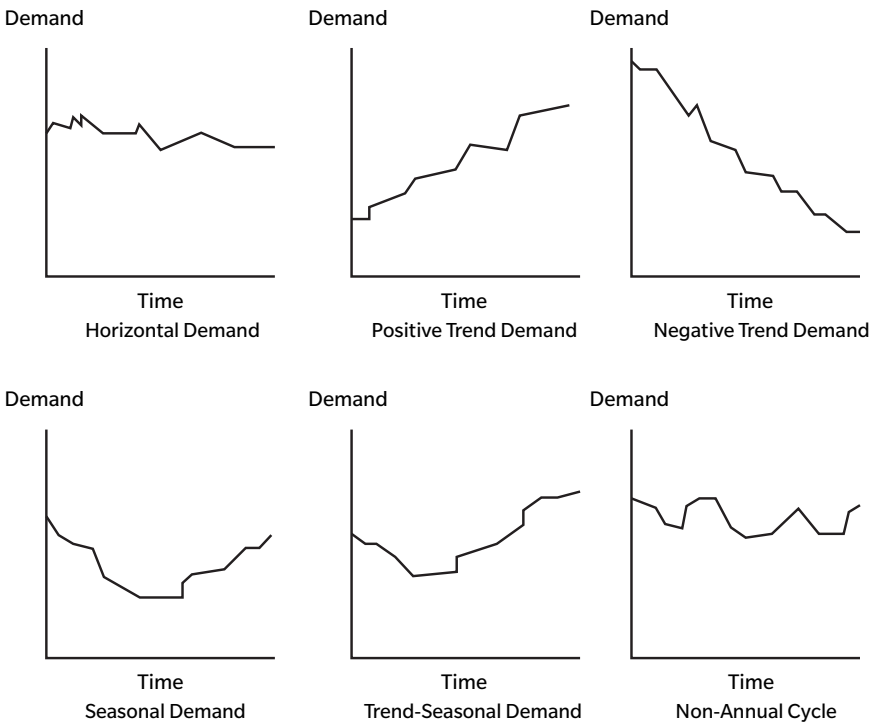



**Diagram 2.2 - Patterns in the Demand. It consists of these patterns**

- **Stable Pattern :** Is a constant horizontal streams of demand. Mature consumer products, such as shampoo, or milk, often exhibit this type of patterns.
- **Seasonality and cycles :** are the regular patterns of repeating highs and lows. Seasonality may be daily, weekly, monthly, or even longer. For example, restaurants experience seasonal patterns during the day with peaks for breakfast, lunch, and dinner.
- **Trend :** identifies the general sloping tendency of demand, either upward or downward, in a linear or nonlinear fashion. New products in the growth phase of the life cycle typically exhibit an upward, nonlinear trend.
- **Shift or Step Change :** is a demand in a one time change, usually due to some external influence on demand such as a major product promotional campaign.
- **Autocorrelation :** describes the relationship of current demand with the past demand. If the values of demand at any given time are highly correlated with demand values from the recent past then we say the demand is highly correlated.
- **Forecast Error :** is the "unexplained" component of demand the seems to be random in nature.

A forecasting process acquires and analyzes information inputs in ways that address all of the relevant components of demand while not overreacting to random changes of demand.

## • Designing a forecasting process

A forecasting process attempts to understand the various components of demand so that it can convert data inputs into reliable predictions of future events.

The forecasting process combines statistical data with judgements from knowledgeable sources. The source of data and judgement may include information systems and experts from both inside and outside the company.

Primary goal of designing a forecasting process is to generate forecasts that are usable, timely and accurate.

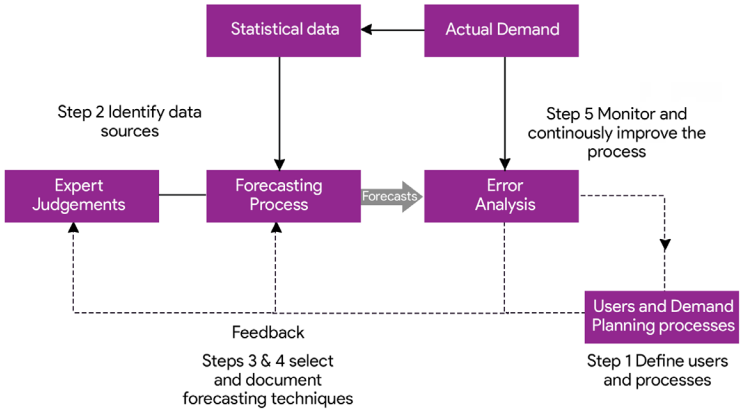



**Diagram 2.3: The Forecasting Process**

Here are the 5 steps for it

- **Identify the users and decision making that the forecast will support.** Forecasting has to be designed with few of the users characteristics and needs in mind
    1. **Time horizon -** forecasting process should suit the period of time over which the users current actions will affect future business performance. Most important is the lead time required to implement decisions influenced by the forecast.
    2. **Level of Detail -** Forecasted are generated for minute details as well. It is important for the forecaster to understand the levels of product and geographical details needed.
    3. **Accuracy vs Cost -** Greater accuracy usually required greater effort and greater forecast system sophistication. It is important to weigh the costs created by forecast errors against the costs of achieving greater accuracy.
    4. **Fit with existing business processes -** In order for it to be useful the forecasting process must be integrated into other business process. Also the logic used to generate forecasts must be easily understood by the users , people are not likely to trust forecasting approaches that they don't understand.

- **Identify likely sources of the best data inputs**

  There are multiple sources of information , including all kinds of experts , corporate records (past programs), the internet , the government (for the state of the economy), suppliers, and customers and sales.

- **Sales forecasting techniques that will most effectively transform data to timely accurate forecasts over the appropriate planning horizon.**

  As a short term planning for stable demand environments , forecasters can usually create suitable forecasts using only simple statistical models based on the historical demand. More volatile and longer time planning situations usually require multiple inputs including judgements, historical data and leading indicator data.

- **Document and apply the proposal technique to the data generated for the appropriate business process.**

  The entire set of assumptions and steps included in the forecasting process should be well understood by all people involved. This enables the users to identify those conditions under which the forecasts are most and least applicable.

- **Monitor the performance of the forecasting process for the continuous improvement**

  Forecasters should carefully track and study the accuracy of the forecasts and work with users to refine the forecasting process . Periodic reviews of the basic assumptions that underlie the forecasts help to keep the process on target for future forecasts.

  Few of the forecastings includes are

- **Judgement based forecasting**
  These are built upon the estimates and opinion of people, most often experts who have related sales or operational experience. Judgement techniques seek to incorporate factors of demand that are difficult to capture in statistical models.

  These models can be used there is lack of quantitative historical information.

- **Grass roots forecasting**
  It is a technique that seeks inputs from people who are in close contact with customers and products. The major limitation with such technique is that experts may unconsciously base their forecasts on their most recent experience rather than the entire set of experiences.

## Example 2 : Two examples of Grassroots Forecasting

Managers at Texas Instruments developed an artificial "stock" market to solve the problem of extracting forecasts from sales representatives. The company issues securities to sales reps that represent different levels of product sales. Then the sales reps can trade securities so that they "invest" on securities representing their best guess of what actual product sales will be. At the end of the sales period, the value of the securities depends on the actual product sales.

For example, it you sell pocket calculators and you expect next year's sales to be 800,000 units , you would try to buy securities denominated "800,000". You would want to unload any securities you have that are denominated "700,000" or "950,000" or other values because you don't expect them to pay off. In this artificial market, if the "800,000" security ends up trading at the highest price, then forecasting managers use that number as the firm's best estimate of next year's calculator volume.

Sport Obermeyer, a designer and producer of ski apparel, uses an innovative grassroots approach to develop forecasts of sales for the items they offer each new season. The company invites retail store managers and sales associates from around the country to come "shop" at a simulated store located at headquarters containing all the new items.

Each sales associate rate the desirability of each item using a seven-point scale. The rating are then tabulated, and the items are ranked based on the average ratings. Managers then create sales forecasts by allocating the total sales estimate for a given category of items to the individual items in that category using a graduated scale based on the past sales. For example, they know from experience that the top 10 most highly rated items in category will account for a certain percentage of sales, the next 10 will account for a lower percentage of sales and so on.

By using such approaches, companies like Texas Instruments and Sport Obermeyer are able to gather unbiased judgements from employees who interact with customers directly.

- **Executive Judgements -** While grassroots approaches are mostly useful for developing short term forecasts for individual products, executive judgement includes the inputs from the high level experienced managers who have exposure to higher experience and access to sources for information.

- **Historical Analogy -** This approach to forecasting uses data and experience from similar products to forecast the demand for a new product. Economists use historical analogy extensively when forecasting business cycles and related developments.

- **Marketing Research -** It bases forecasts on the purchasing patterns and attitudes of current and potential customers. Marketers have developed a wide range of tools for evaluating the purchase patterns and attitudes of current and potential buyers of a product, including customer surveys, interviews and focus groups. This technique assumes that no single group or person is likely to have access to all the key inputs in a demand forecasting process.

- **Delphi Method -** It develops the forecasts by asking a panel of experts to individually respond to as a series of questions. The forecaster compiles and analyzes the respondents inputs and shares the data with the group. This answer - feedback process is repeated until a consensus is achieved that reflects input from all of the experts while preventing any single individual from dominating the process.

- **Statistical model based forecasting -** It transform the statistical model based forecasting techniques transform numerical data into. Forecasts using one of the three methods :

| Forecasting Method | Amounts of Historical Data | Data Pattern | Forecast Horizon | Preparation Time | Personal Background |
|---|---|---|---|---|---|
| Time Series: Moving average and exponential smoothing based methods | 10 to 15 observations to set up parameters | Stable, trend and seasonality | Short | Short | Little to moderate sophistication |
| Time Series: Regression | 10 to 20; for seasonality at least 5 per season | Trend and seasonality | Short to Medium | Short | Moderate sophistication |
| Casual Modelling | 10 observations per each independent variable | Complex Patterns | Short, Medium or Long | Long development time, short time for implementation | Considerable Sophistication |
| Simulation Models and focused forecasting | 50 or more observations | Distributions of demand creating processes must be approximated | Medium or Long | Long | High Sophistication |

**Table 2.2 : Demand Planning of Different Time Horizons**

- **Time-series analysis model :** Computes forecasts using the historical data arranged in the order of occurrence . Forecasting models that are based only on the series of past demands assume that a demand

pattern of the past will continue in the future. Thus if some new event changes the underlying drivers of demand then these model will not work well. Forecasts are generated by summing the weighted values of the past demands, and the weighing schemes range from simple to very complex. The type of weighing used depends upon the demand pattern. While this simple approach is sometimes affected, it ignores the trend seasonal or other components or random variations at present.

- **Model Average Models :** Another way to create forecasts that reflect changes in demand while dampening or smoothing out erratic movements is to forecast future demand as a simple average of past demand. This model is used when the demand pattern is relatively stable , without trend or seasonality . A moving average forecasting model computes a forecast as an average of demands over a number of immediate past period (n) as shown in equation :

$$F_{t+1} = \frac{d_t + d_{t-1} + d_{t-2} + \cdots d_{t-n}}{n}$$

where :
F - is the forecast for the next period
t - is the demand from the most recent period
n - is the number of periods used to compute the moving average

- **Exponential Smoothing -** Another time series model used for demand pattern assigns weights to a moving average calculation in a systematic way. In this approach , an exponentially smaller weights is applied to each demand that occurred farther back in time. Each weight is a certain percentage smaller than the weight assigned to demand data for the previous period.

$$F_{t+1} = \alpha d_t + (1 - \alpha) F_t$$

Where:
α - is a constant between 0 & 1, called the smoothing coefficient
t - is the forecast for a given period is a linear combination of the most recent subsequent period's result.
F - is the forecast for the period.

- **Estimating trends**
  - » **Exponential smoothing with trend effects -** early users of the exponential smoothing model so started to augment that simple model to accommodate trend and other components of demand in a more predictive way. The following equations show how to change each period forecast to include an adjustment for a known trend.

$FIT_{t+1} = F_{t+1} + T_{t+1}$ $F_{t+1} = FIT_t + \alpha (d_t - FIT_t)$ $F_{t+1} = T_t + \beta (F_{t+1} - FIT_t)$

Where :

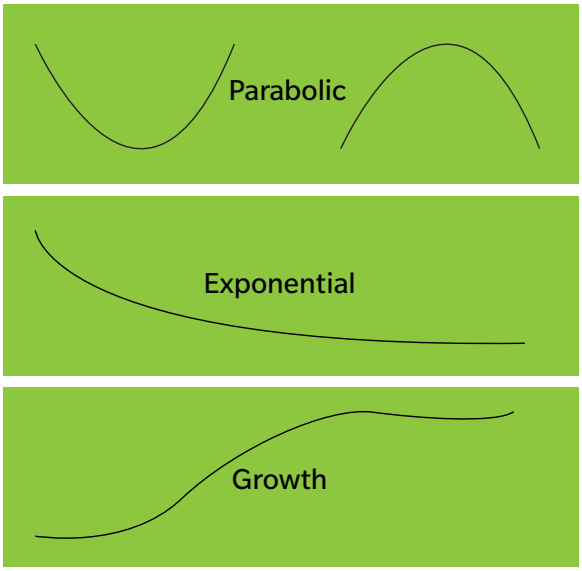
T - The forecast including trend for period t

The "base" forecast for the period t from the simple exponential smoothing model

The forecast of the trend component of demand for period t

The base smoothing coefficient

» **Determining trend factors -** The trend component of a time series normally results from some market force that causes a general rise or decline in values over time. Nothing dictates that any long term trend must follow any of these familiar curves.




$$d_t = a + b \times t$$

- **Simple Linear Regression : Time Series**

  Regression analysis is the most commonly used method for estimating relationships between leading indicators and demand. Simple linear regression is a technique that finds "optimal" values for the parameters 'a' and 'b' in the equation

$$\sum_{t=1}^{t=n} (d_t - F_t)^2$$

Where,

Actual demand value for period t

Forecasted demand from the regression equation for period t

- **Adjusting forecasts for seasonality**

  Seasonal variations in demand can be estimated by applying a seasonal index to adjust forecast values for each seasonal time period. Here the seasonal index is an adjustment factor applied to forecasts to account for seasonal changes or cycles in demand. Season could be either of the following; daily, weekly, monthly or in larger periods . The seasonal index is computed by dividing each period's actual demand by an estimate of the average (or base) demand across all periods in complete seasonal cycle; that is; the average demand that would be expected if no seasonality existed.

- **Casual models**

  Where time series models use only past demand values as indicators of future demand, casual models use other independent, observed data to reprint demand. These models concentrate on external factors that are thought to cause the demand. Regression analysis is the most commonly used method for estimating relationships between leading indicators and demand, the. Technique can be extended to include multiple indicators in multiple regression analysis . In this approach, the forecaster would gather past data describing demand and multiple independent indicators considered important as predictors of demand. The regression analysis computes the coefficients (indicator weights) forming an equation the best describes the past relationships between the predictors and the actual demand data. The equation is then used to forecast future values of demand based on the observed values of the leading indicators.

  $$\text{Sales Forecast} = B + b_d(D) + b_a(A) + b_f(A) + b_s(S)$$

  Where,

  B = Base sales (computed y-intercept)

  D = Disposable personal income

  A = Advertise expenditures

  F = Fuel prices

  S = Sales from prior year

  Each of the indicator weights (values of b) is computed by a regression method. Each value of b represents the incremental contribution of the corresponding leading indicator to the sales forecast,

- **Simulation models**

  Simulation models are sophisticated mathematical programs that offer forecasters the ability to evaluate different business scenarios that might yield different demand outcomes. This evaluation helps forecasters to better understand how different variables and drivers of demand relate to one another. The focused forecasting process asks for managers to suggest rules of thumb that should be followed when developing forecasts. These types of rules of thumb are embedded in a simulation model, and their usefulness is then tested by estimating how effective they collectively would have been in predicting demand data from the past. The forecaster then makes new forecasters using the combination of rules that would have provided the best forecasts for the past demands . Managers from different functional areas adjust the forecasts as they see fit. This approach has delivered better results then exponential

smoothing or other time series based model has given. However the focused forecasting requires mode preparation and user involvement.

**Assessing the performance of the forecasting process**

The primary measure of forecasting performance is forecast error. The forecast error is defined as the actual demand value minus the forecasted demand value for a given time period . Positive forecast error indicates an overly pessimistic forecast.; negative value indicates an overly optimistic forecast.

Forecast errors can be examined to determine two primary aspects of forecast performance over time : forecast accuracy and forecast bias. **Forecast accuracy** measures how closely the forecast was too high or two low, reduces accuracy. **Forecast bias**, on the other hand , is simply the average error. Forecasting bias indicates the tendency of a forecasting technique to continually overpredict or underpredict demand.

» Forecast bias is the average forecast error over a number of periods:

$$\text{Bias} = \text{Mean Forecast Error (MFE)} = \sum_{t=1}^{n} \frac{(d_t - F_t)}{n}$$

» A positive forecast bias indicates that over time forecasts tend to be low; a negative bais indicates that forecasts tend to be too high. For comparability's sake, forecasters often compute average error (bias) on a percentage bias. This metric is known as mean percent error (MPE) and is calculated as

$$\text{Mean Percent Error (MPE)} = \frac{\sum_{t=1}^{n} \frac{d_t - F_t}{d_t} \times 100}{n}$$

» Remember that both average forecast error and mean percent error are good indicators of bias, but they do not necessarily provide good indications of forecast accuracy. Forecasts that are too low or too high are both undesirable . The simplest measure of forecast accuracy is known as mean absolute deviation (or the mean absolute error). This measure provides the average size of forecast errors, irrespective of their directions.

$$\text{Mean Absolute Deviation (MAD)} = \frac{\sum_{t=1}^{n} |d_t - F_t|}{n}$$

» For purpose of comparability across products, forecasters sometimes adjust the MAD to create a related metric, the mean absolute percentage error (MAPE). The MAPE indicates how large errors are relative to the actual demand quantities

$$\text{Mean Absolute Percent Error (MAPE)} = \frac{\sum_{t=1}^{n} \frac{|d_t - F_t|}{d_t} \times 100}{n}$$

» Though intuitively appealing, measures like MAD and MAPE are sometimes inadequate as measures of forecast accuracy in that they do not recognize that forecasts that are really far off the mark may be more harmful to the user than forecasts that miss the actual demand by the small amount. To deal with this issue of sensitivity of the magnitude of the errors, researchers developed the mean squared error (MSE)

$$\text{Mean Square Error (MSE)} = \frac{\sum_{t=1}^{n} (d_t - F_t)^2}{n-1}$$

» Because of the squared term, the MSE gives exponentially more weight to larger and larger errors. The MSE equation looks like the formula for the variance of the forecast errors. However, there are some important differences. The variance of errors would use the actual forecast errors and the mean of the forecast errors.

$$\text{Forecast error variance} = \frac{\sum_{t=1}^{n} (e_t - \overline{e})^2}{n-1}$$

» At the same time , MSE usually does give a decent approximation of the variance of forecast errors. Thus the square root of MSE provides a good approximation of the standard deviation . For this reason, forecasters often track the root mean squared error (RMSE)

$$\text{Root mean squared error (RMSE)} = \sqrt{MSE}$$

- **Tracking forecast error acceptability**

Forecasters generally use forecasting metrics such as MAD and MSE to quickly and continuously evaluate forecasting models , sometimes for thousands of different products at a time. In this environment, metrics are often used to identify exceptional cases that require adjustments to model parameters. Managers need a simple test for determining when the forecast error is unacceptable. One way to test the forecast error is to develop a control chart in which forecast errors are plotted and compared to expected upper and lower control limits

- **Situational drivers of forecast accuracy**

Forecasters want to develop accurate forecasts. However some demand forecasting situations create greater challenges than others. The following “rules” give an indication of how situational characteristics tend to affect forecast accuracy.

Rule 1: Short term forecasts are usually more accurate than long term forecasts - As the time horizons for forecasting increases, more and more potentially unknown factors can affect demand.

Rule 2 : Forecasts of aggregate demand are usually more accurate than forecasts of demand at detailed levels. - Aggregate forecasts benefit from a cancellation of errors that exist in item level forecasts. Aggregate demand is more stable and predictable.

Rule 3 : Forecasts developed using multiple information sources are usually more accurate than forecasts developed from a single source. - Many different market forces Amy drive for a given good or service. It is difficult for any single source of information to comprehend all the factors. A forecast created by combining information from multiple different sources is likely to reflect a more complete and unbiased picture of actual demand patterns. It Is unlikely that all source will be “wrong” in the same direction.

# PART 3

## Demand Management

## Demand Management

Forecasting is essentially a reactive approach that considers fluctuations in demand to be mostly outside the firms control. By just not forecasting and reacting to changes in demand, however business executives would prefer to influence the timing, patterned certainty of demand to whatever extent they can. This could be achieved by demand management that adjusts product characteristics including price , promotion and availability .

The purpose is to influence product demands to achieve sales objectives and to accommodate the supply chain resources and capacities that the firm has in place.

Demand Management is especially important when customers demands fluctuate. In an unpredictable way. These fluctuations cause operational inefficiencies all across the supply chain which includes :

- Increasing the reducing the capacities to meet the varying demand from the market.
- Backlogging certain order to make up for the difference in demand fluctuations
- Dissatisfaction from the customers with the systems inability to meet all demands.
- Buffering the system by involving the use of excessive inventories (safety stocks), lead times with a cushion (safety lead time or excessive resources (safety capacity).

In order to be effective , demand management requires coordination of many sources of demand information. Demand management planning often crosses organizational boundaries in the supply chain. It requires the sales, markerg, supply management and operational personal as well as suppliers and intermediate customers to work together in planning strategies for developing and fulfilling orders.

Managers try to manage demand by using variants of three basic tactics

1. **Influence the timing or quantity of demand through pricing changes , promotions or sales incentives -** These moves are usually intended to increase demand during the low periods and to reduce or postpone demand during peak periods.

2. **Manage the timing of order fulfillment -** In some situations, it is possible to negotiate with customers regarding when they will take delivery of their products. Information systems can be used to inform customers of the availability of certain products including the expected delivery date.

3. **Substitute by encouraging customers to shift their orders from one product to another, or from one provider to another. -** The information system enables the sales representative to know exactly which products are immediately available and marketing managers price products dynamically to move those items that are in stock

Characteristics of the product, customers lead time expectations and their operations environment all influence how the above tactics are employed in a demand management. In every case the important goal of demand management is to match demand and operational capacity in order to attain the business competitive objectives.

**Improving the constraints on demand planning**

Most of the firms nowadays redesigning operations across their supply chain to facilitate more effective demand planning and order fulfillment. Improvement initiatives are aimed at changing information sharing systems, manufacturing and shrive processes, supply chain relationships and even the product design itself, so that the company reduce both the magnitude and impact of forecast errors on its operations

## Example 1: Destination Maternity Corporation, Customer Quickstep

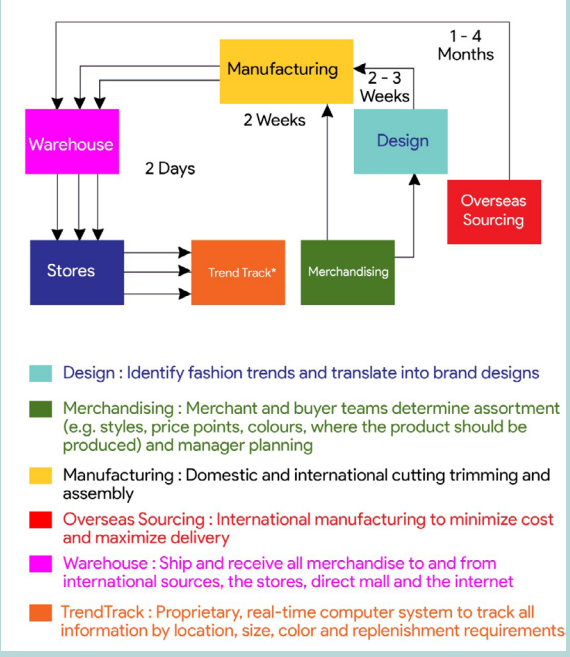
Destination Maternity Corporation (originally known as Mothers Work, Inc.) is a leading designer, manufacturer, and marketer of maternity fashion in the United States, with over 900 locations worldwide. Destination was found by president and chief creative officer Rebecca Matthias in 1982 in the front closet of her Philadelphia home, with the investment of $10,000 of her own savings. A civil engineer and pregnant with her first child, Ms Matthias was unable to find clothing appropriate to her role in the business world.

Since the time of its initial public offering in March 1993, Destination has increased its store base by over 1300 percent, and grown financially to more than 10 times its original size. A critical success factor has been the company's ability to gather extensive point of sale information at each store.

Managers developed an information system with the following capabilities:

- Capture all customer information and create a buying history
- Run individual mailing lists by due date
- Receive alerts about any operational errors that may have occurred the previous day
- Review all orders on the way to their stories
- Make customer unique price tickets
- Send and receive digital photos
- Provide sales trend information

The system also provides such features as custom profiles for each store, daily inventory replenishment, and daily updated selling information for each style.




Complementing the information systems are the company's fast-turn, in-house design, and quick response material sourcing processes (shown below left). By coupling current and accurate information with a very responsive supply chain, destination has been able to avoid lost sales per square foot. Destination provides an excellent example of how improving the constraints that otherwise limit the effectiveness of the demand planning system can yield big operational and financial benefits.

**Improving information accuracy and timelines**

Predicting the sales of a new line of merchandise is difficult. Once the firm launches a product line it needs quick information about the. Markets response to the. New goods Information systems that. Rapidly collect and distribute accurate sales information are. Important in the fashion industry and in many other industries as well. Quick sales data. Collection is important because the current data is more relevant for forecasting the future sales. Initial forecasts made the product launch can be highly improved by incorporated early sales data.. In addition rapid access to customer sales information coupled with an operation systems capable of rapid response , decreases a firm's reliance on forecasting into the future.

## Example 2: Calyx and Corolla Delivers Freshness by Redesigning the Supply Chain

Calyx and Corolla is a company is a company that sells flowers from growers around the world to customers located around the world. The company promotes itself that their flowers will last 5-10 days longer than most others. How are they able to deliver on this promise ? Most traditional florists must deal with a very long supply chain. Growers grow the flowers. Distributors buy them and sell them to regional sellers, who in turn sell them to local florists. At each stage, the flowers are produced or purchased based on the party's forecast of demand.

A typical flower can last about 19 days, once it has been cut. The traditional supply chain consumers supply chain consumes about 10 to 11 days of this time. The founders of Calyx and Corolla redesigned the supply chain to reduce lead time by working directly with the growers. Orders received from customers (in response to printed catalogs or the internet) are placed by Calyx and Corolla directly with the growers, who then cut, package, and ship the flowers directly to the customer via FedEx. Consequently, flowers delivered this way spend three days or less in the supply chain. The benefit for the customer is that they arrive at their destination fresher, and they also last together. The benefit of Calyx and Corolla is that they only need to forecast demand for three to four days into the future in order to arrange for sufficient product and transportation capacities. Their competitors have to forecast demand for several weeks into the future.

- **Reducing Lead Time**

  Basic fact of forecasting that the longer time period over which you have to forecast , the greater the forecast. Error. A forecast of demand of 2 years from now is far less accurate than the forecast for next month. In most of the cases, the number of period that managers have to forecast. Into the future determined by the order to delivery (OTD) lead time provided by the supply chain. That is., the time required to source, make, and deliver the product. The reducing lead time improves forecast accuracy , because shorter lead times require shorter term forecasts. Speeding up or eliminating process steps that are redundant unnecessary or poorly executed lead time.

- **Redesigning the product**

  For a firm offering a wide range of products , forecasting is really challenging . A postponable product is designed so that it can be configured to its final form quickly and inexpensively once actual customer demand is known. In this operation system, only components, not finished goods are stocked near sources of demand. The process largely focuses on the few individual components and not many different end item configurations.

## Example 3: HP Improves the constraints on Forecasting through Postponement

While the "guts" of an inkjet printer are basically the same regardless of where they are sold. The instructions manuals, power supplies and cables have to be made different to accommodate differences in language and electrical grids in various countries. Initially, HP forecasted each country's demand for inkjet printers and then stocked all printer variant according to the forecasts. However, forecasts were never accurate enough to make this approach work - inventories were high, expediting was common and use customer service was low.

To solve this problem, HP decided to produce and stock only the generic inkjet printer bases, along with seperate power supplies, cables, and instruction manuals, in regional warehouses around the world. The warehouses act as both storage locations and as light assembly plants. Once an order is received for an inkjet printer for germany, for example, the order is sent to the nearest regional warehouses. Thus, a generic printer base is withdrawn from stock and paired with the appropriate power supply, cable, and instructional manual. The entire system is then tested and packed in country specific packaging. HP has found that this approach has reduced total landed cost (manufacturing, shipping, and inventory) by 25 percent. In addition, they reduced total inventories by 50 percent while simultaneously increasing customer order fill rates significantly.

- **Collaborating and sharing information**

  The need for forecasting partially arises from the lack of sharing information across different stages of. The supply chain , Suppliers make assumptions about the actions of their customers and vice versa. Many firms today use both formal and informal approaches to share planning information with their suppliers and customers , including forecasts of product demand and planned product promotions.

  The planning partners then make commitments to a collaboratively established overall sales and production plan, taking into account the demands and constraints of the various organizations. This approach reduces risk associated with forecast errors; it reduces the inventories the supply chain players typically hold to guard against such risks and it improves customer service levels by reducing lead times.

  One systematic process for improving collaboration and information sharing in supply chain is known as collaborative planning , forecasting and replenishment

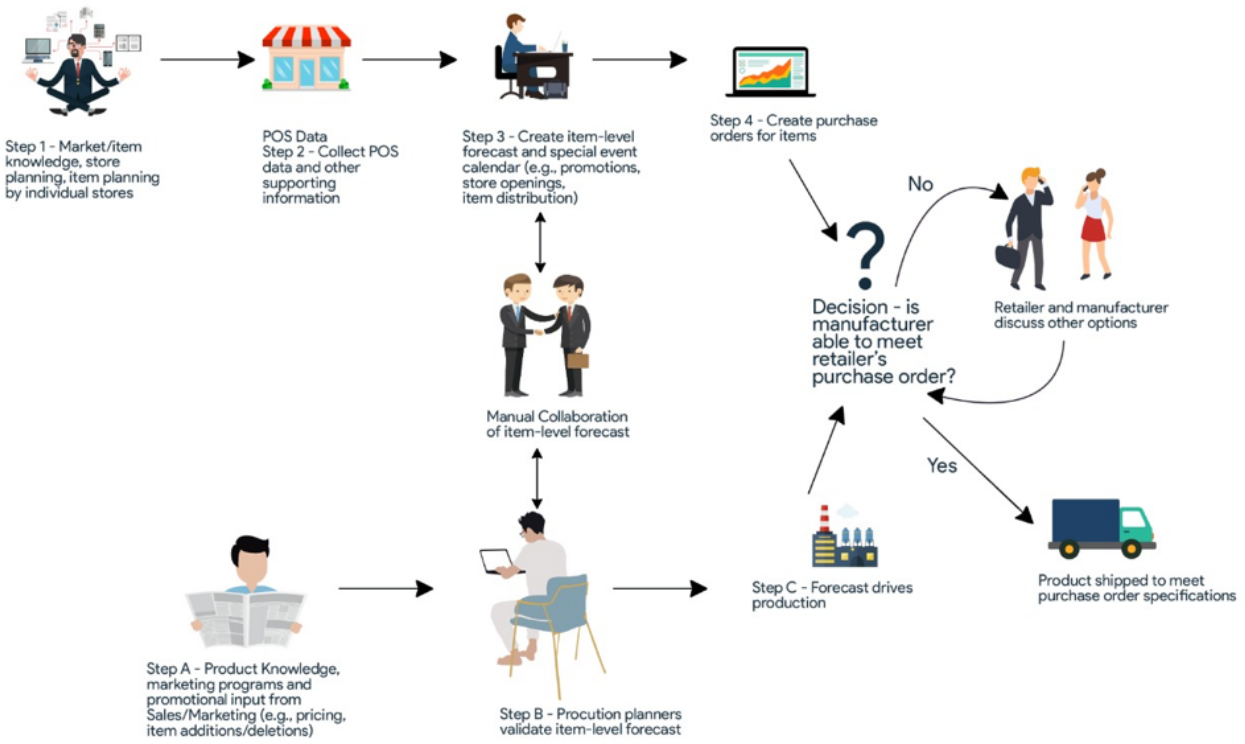



**Diagram 3.1 : The CPFR Approach**

## CPFR process consist of collaborative activities like

- Market Planning - partners collaboratively discuss such issues as the introduction of new products, store closing/opening , changing inventories policies and product promotions
- Demand and Resource planning - customer demand and shipping requirements are forecasted
- Execution - Orders placed , delivered and received. It includes preparation of shipments and recordings of dales . Since logistics / distribution is critical , third party logistics providers may be included in the CPFR effort.
- Analysis - Execution is monitored and key performance metrics are collected with the. Goal of identifying opportunities for future improvement.

# PART 4

## Process mapping and Analysis

## Process mapping and Analysis

Process mapping and analysis is a technique for documenting activities in a detailed compact and graphic form to help managers understand processes and highlight areas for potential improvements. This technique generates a process blueprint and supplies nearly all of the information needed to effectively evaluate the process.

| Desired Outcomes | Output Measures | Process Measures |
|---|---|---|
| **Cost** | Actual cost per unit | Number of steps in the process (more steps should lead to higher costs) |
| | Actual cost vs. Standard cost | Number of people involved in the process (more people involved, the higher the costs) |
| | Target Prices - relation of actual costs to target or desired costs | Average setup costs (higher setup costs should lead to larger batch quantities, which should increase costs) |
| | Percentage cost saving achieved | Percentage of unique components (the more unique items, the higher the costs) |
| | Reduction of administrative/overhead costs | |
| **Quality** | Total Cost of Quality | Number of times an item is handled (more handling creates more opportunities for quality problems) |
| | Percentage of products done right the first time | Number of steps in the process |
| | Actual yield rates vs. standard yield rate | The number of times that the item is allowed to stop or to go into inventory (more items, more opportunities for quality problems) |
| | Percentage of work reworked or rejected or held for further inspection | Number of inspections (more inspection - an indication of quality problems) |
| | Defective parts per million (PPM) | Number of steps in the process (more steps increase the probability of more quality defects) |
| | Customer quality incidents | |
| | Percentage and number of defect-free shipments | |
| **Availability** | Amount of inventory | Number of delays in the process (more delays create more unanticipated stoppages) |
| | Order fill-rates | |
| | Fill-rate by line | |
| | On-time arrivals | |
| | Number of lines/customers shut down because of supply shortages | |
| **Lead Time** | Actual lead time to built a unit | Number of steps (the more steps, the longer the lead time) |
| | Actual lead time vs standard lead time | Average setup time (as setup time increase, order quantities go up, and total lead times are increased) |
| | Percentage reduction in lead time | Distance covered by the process (the greater the distance, the longer the transport time) |
| | | The number of people who touch the order (more touches create more costs, time, and potential errors) |

**Table 4.1 : Examples of Commonly used Measures**

## Step 1 : Identify the Desired Outcomes in advance

It is important to know what the objective of process is and what are we trying to achieve as an outcome . Metrics are critical In making these desired outcomes meaningful to those involved with the process. The below table contains some of the more commonly used output metrics (measured at the end of the process) and process metrics (traits of the process that affect outcomes being pursued)

## Step 2 : Identify and bound the critical process

The second step involves identifying and bounding the process that is most important to our desired outcome. A critical process typically exhibits at least one of the following traits.

1. Bottleneck process - one that limits capacity for the overall system
2. Consumes lot of resources - one that offers the greatest potential for cost savings
3. Exhibits greater level of variance - one that offers potential for improved reliability and capacity gains
4. Visible to customer - one that affects customers perception of value
5. Shared process - one that feeds multiple downstream process
6. Process that is related to unique skill or core competency - one that serves to differentiate us from competitors

It is important to bound or define the limits of the critical process. Without bounds a process study runs a real risk of never being completed . Bounding includes defining physical starting and ending points for process analysis , as well as defining the operating conditions and demands to be considered in the analysis. A manager has to decide where to study the process under low demand, average demand or peak demand conditions.

## Step 3 : Document the existing process ("the current map")

Describing the current state of a process can be difficult. Inefficiencies and poor designs in the process may reflect poorly on particular managers or workers, so that may be reluctant to offer process information. It is important for analysts to speak directly with the people who actually perform the process, not just those who manage the workers. Otherwise, the analyst might develop a distorted view of the "actual" process. Finally, the analyst must be aware that their presence near the workers can alter the way in which work is performed.

An effective way to document and communicate the current state of a process is to develop a process map or diagram. By using a set of symbols in such a map the analyst can graphically present how the inputs, outputs, flows and activities of a process are linked together.

Process mapping and analysis can potentially be complex and time consuming, but there are some general guidelines that can make this task simpler and easier to manage.

- Identify minimum acceptable levels of details
- Use different process mapping and analysis technique
- Watch out for hidden steps in a process

| Activity Classification | Symbol | Major Action/Result |
|---|---|---|
| Operation | o | Decides, produces, does, accomplishes, makes, uses |
| Transportation | ⇒ | Moves, changes location |
| Inspection | □ | Verifies, checks, makes sure, measures |
| Delay | D | Blocks, starves, interferes, temporary stop |
| Storage | ▽ | Keeps, safeguards |

**Table 4.2 : Process Activity Types**

### Step 4 : Analyze the process and identify opportunities for improvement

In this step, we determine if the process requires minor or radical changes to it. If the current process is basically acceptable in its structure and operation, all that may be needed are repositioning and alterations of existing activities. Alternatively, if manager decide that ht process requires major changes, it is sometimes better to throw out the current process and to redesign a new one starting with clean state.

The following paragraph describes a three stage analysis for generating improvement ideas :

1. **Assessment - Mapping Value :** On this assessment, an analyst can classify each activity into one of four different categories : value adding / necessary but not value adding , waste generating and question mark.
    - A value adding activity moves the product close to the form or location that the customer desires
    - Necessary but not value adding are those activities that do not add value directly but is necessary before value adding activity can take place.
    - Waste generating activity are those that consumes resources and time without returning any form of value
    - Question mark activity are those activity that cannot be easily categorized into one of the prior categories (value, necessary but not value adding, waste)

2. **Dispositioning :** Dispositioning involves deciding what to do with each specific activity at the time of analysis. In general there are four dispositioning options available.
    - Keep : Leave the activity intact
    - Combine : Joint the activity with others that do the same or similar things to improve the efficiency of the process
    - Rethink : Reevaluates an activity that produces a favorable outcome (value added or non value added but essential) but does so inefficiently
    - Eliminate : Usually appropriate for wasteful activities

3. **Repositioning :** Repositioning looks on which path an activity should be positioned within the overall process. Within every process there are two types of path : critical paths and non- critical paths. The critical path is the set of sequential activities with the largest total of activity time. This path is critical because it determines the overall lead time of the process. By moving activities from critical to non critical paths can be shorten the total order lead time for the process.

    Yet another way to improve the process performance is to break a single path of activities into parallel paths. Many time these types of changes are not possible because of technical constraints (i.e one activity must precede another) or resource constraints (eg. Making parallel paths would increase the number of workers required)

4. **Principles of process improvement :** Improvement opportunities are unique to each process but there are certain principles that one can draw upon making the process evaluations. Managers usually get better at identifying improvement opportunities as they gain experience in multiple process mapping and analysis project.

## Step 5 : Recommend Appropriate changes to the process ("the future state map")

Once a list of possible changes for improvement has been made, it is important to bring together representatives from the various stakeholders groups to evaluate and prioritize the changes. Stakeholders in a process include suppliers and customers of the process, workers and support personnel involved in the process and various functional managers.

The prioritization of possible improvements of the process could be classified into

1. Make the changes immediately
2. Postpone the change until sufficient resources and capabilities become available
3. Determine that the change is not ultimately desirable or feasible.

## Step 6 : Implement the changes and monitor performance

Process improvement is usually an iterative, trial and error activity. Consequently, feedback mechanism

should be put into place whenever significant process change is implemented so that managers can evaluate its impacts and make adjustments as needed. In some cases a pilot study might be done to verify the benefits of a process change. In others a wholesale, radical change might be attempted very quickly to shake up existing infrastructure and to overcome barriers to change that often arise.

Other process mapping tools

1. **Process flow diagrams -** A technique used to indicate the general flow of plant processes and equipment
2. **Value Stream mapping -** A mapping technique that analyzes the flow of material and information needed to bring a product to the customer
3. **Service Blueprinting -** A technique for mapping an entire service system, so that the process can be analyzed, monitored and improved in its ability to satisfy the needs of the customer
4. **Swim lanes -** A visual element used in the process flow diagrams or flowcharts that organizes the activities into groups based on the major types of task being carried out or on who is responsible for those activities.

## Process Structures

Managers must design processes based on what kind of work needs to be done. Different process structures provide different capabilities. Process structure determines how inputs, activities, flows, and outputs of a process are organized. Within a supply chain, each organization must select the process structures that are appropriate considering their competitive priorities of quality, timelines, cost, flexibility and innovation.

To better link a products life cycle and marketing decision with operations capabilities. Hayes and Wheelwright developed the product process matrix . They observed the process progress through the lifecycle just as products do. Although developed for manifesting , the product process matrix also describes many service process. To achieve high performance, a firm's process structure must be aligned with its competitive priorities and marketing strategies.

The matrix shows five process structures along the diagonal based on output volume and variety: project, Job search, batch and repetitive process and continuous process.

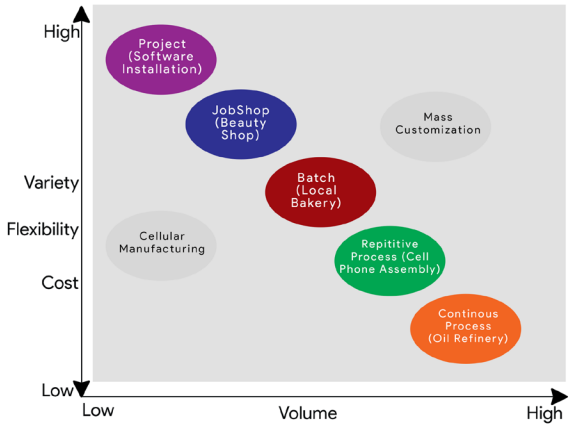



**Diagram 4.2 : Product - Process Matrix**

## Aligning Process Structure and Market Orientation

There are different process structures involve different decisions about whether a product is designed and produced before a customer order is placed or after the order is placed. This decision determines how the firm competes in the marketplace. There are four different marketing orientations ; each delivers a different level of service in terms of lead time and customization. To be effective, an organization's process structure must fit with its marketing orientation

Products that firms engineer to order (ETO) are designed for individual customers and generally long lead times. The basic design of Make to order (MTO) products covers the need of brand group of customers , but allows for some customization during production. Like ETO a customer order triggers activities at the very early stages of production. Because the design does not start from scratch, the lead time for MTO is less than the ETO.

The designs of the components and module in assemble to order (ATO) products are standardized and do not change with customer orders. However the components and modules can be assembled in different ways to create and product configurations that meet individual customer needs. Raw materials and components are produced and stored in inventory but final assemble is postponed until the customer orders.

Groceries, retail clothing, books and electronics and cars are examples of make to stock (MTS). Products . So that products are immediately available, finished products are made in advance of customer orders and held in inventory . This firms must make products based on forecasts of customer demand. MTS items are typically standardized, mature products. Repetitive assembly lines and continues processes are typically used for MTS products

## Unique aspects of service processes

Although the product - process matrix can be used to describe services , it does not address the fact that customers often participate in service processes , customer contact refers to the presence of the customer in a service process . Services range from those with high customer contact such as haircut to those with low customer contact such as package delivery. Contact with the customer creates unique challenges in designing, controlling , and operating service processes.

## Service Process Matrix

It categorizes service based on the degree of customization/customer interaction and labor/capital intensity involved. Services in the same industry can compete in different ways by adopting process structures specified in this matrix.

1. **Professional Services -** Professional services tend to be time consuming and costly because providers are highly skilled and educated.
2. **Service Factory -** Customer contact , customization and labor intensity are low while investment in facilities and equipment is

high

3. **Service Shops -** It has a high degree of capital intensity and high customer interaction/customization. Keeping up to date on new technology and scheduling to ensure effective utilization of technology are key operations issues.
4. **Mass Services -** These services have low customer interactions / customization and high labor intensity.

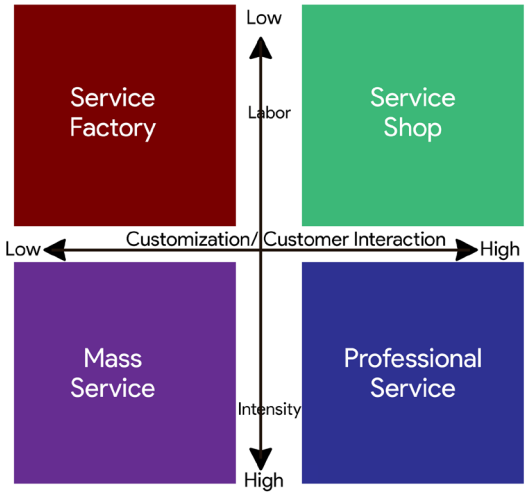



**Diagram 4.3 : Service Process Matrix**

## Managing Front Office and Back Office Processes

While some processes within a company require customer involvement and interaction, others do not. Processes involving contact are referred to as front-office processes. Those that are behind the scenes are called back-office processes.

Depending on the nature of the service, front office and back office processes can be coupled or separated from each other. With decoupling each process can be managed separately, creating opportunities for efficiency gains .

The ability to decouple services allow different processes to be done by different supply chain members who are dispersed globally.

## Service blueprinting

Service blueprinting is a tool that focuses on understanding the interfaces between customers and service providers, technology, and other key aspects of the process. A cross functional team identifies the service process to be blueprinted, documents the process step by step, analyzes process enhancements or causes of problems, implements improvements and monitors the results.

Service blueprinting differed from process mapping in that it focuses on the following that are particular to services:

- Customer actions include all of the steps that customers take as part of the service delivery process
- Front-office/visible contact employee actions are the actions of frontline contact employees that occur as part of a face to face encounter with customers.
- Back-office/invisible contact employee actions are non visible interactions with customers
- Smart processes are all activities carried. Out by employees who do not have direct contact
- Physical evidence represents all the tangible that customers see or collect during their contact with a company.

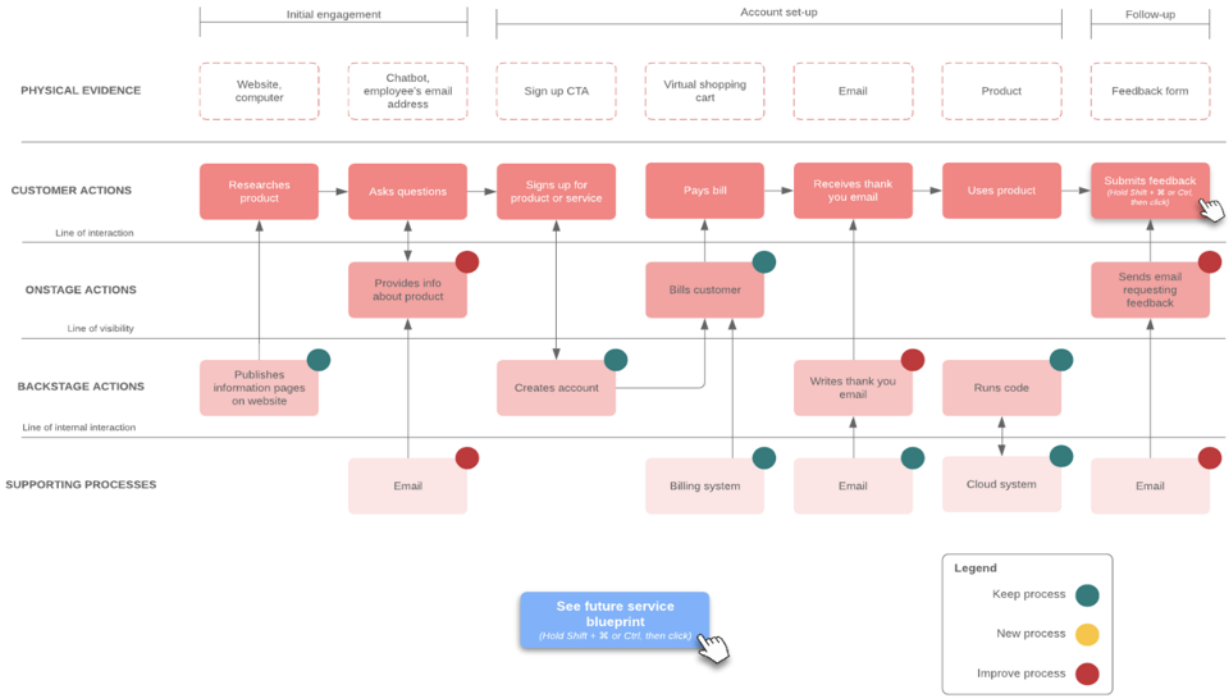



**Diagram 4.4 : Service Blue Printing Example 1**

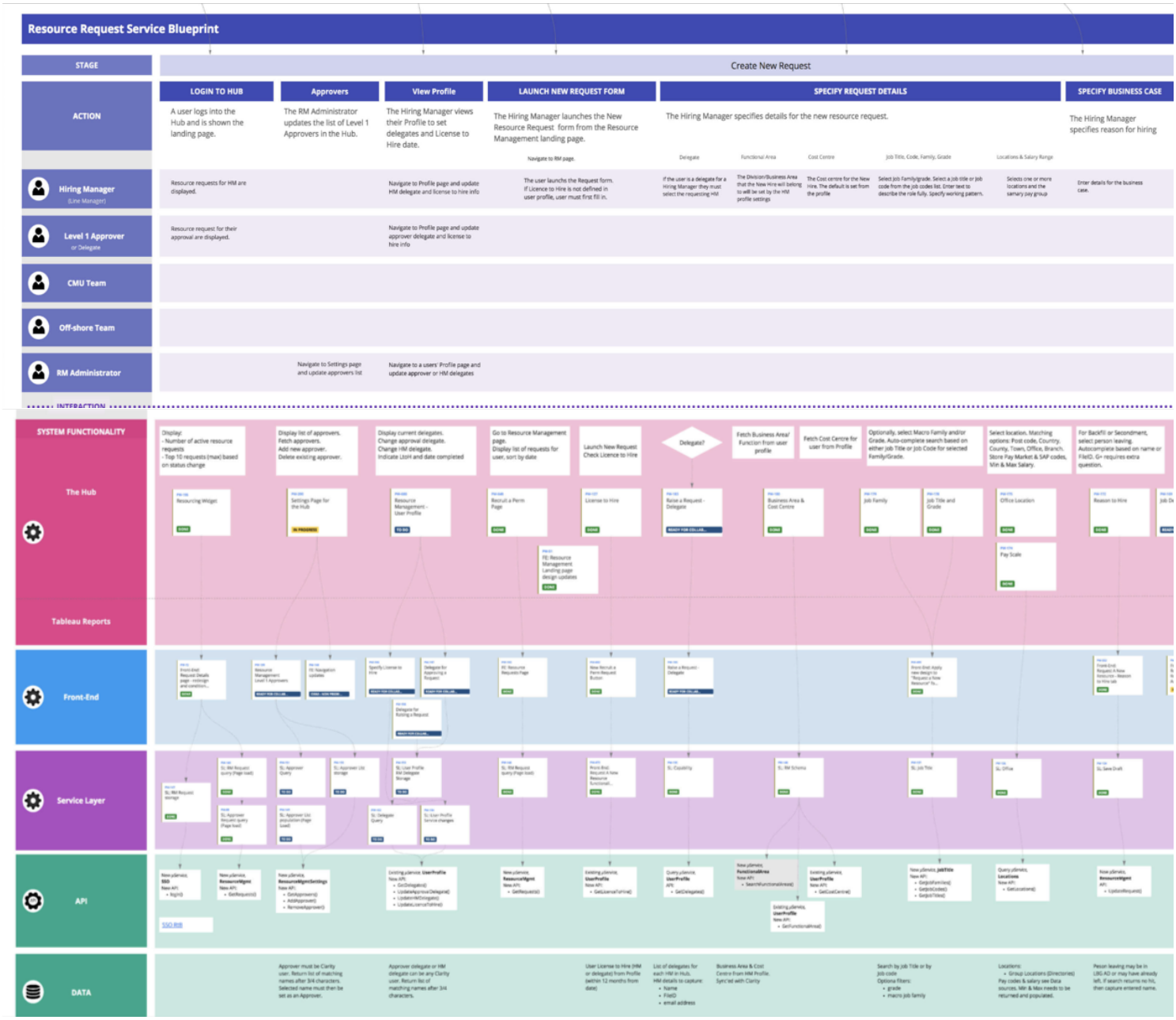



**Diagram 4.5 : Service Blueprinting Example 2**

# PART 5

## Sales and Operation Planning

## Sales and Operation Planning

S&OP is a process to develop tactical plan by integrating customer- focused marketing plans for new and existing products with the operational management of the supply chain

Sales and Operation is more of the intermediate range planning , it focuses on a time period ranging from 3 to 18 months. Typically it is broken input time increments that are weekly , monthly or quarterly depending on the specific needs of the company .

Planning takes place at the aggregated , product family level though it may include some detailed planning for critical items and special events such as new product launches . The process brings together all the plans for the business (sales, marketing ,new products , logistics manufacturing , supply and financial ) into one integrated set of plans. The So&P often varies from company to company but there are certain features which are common to all

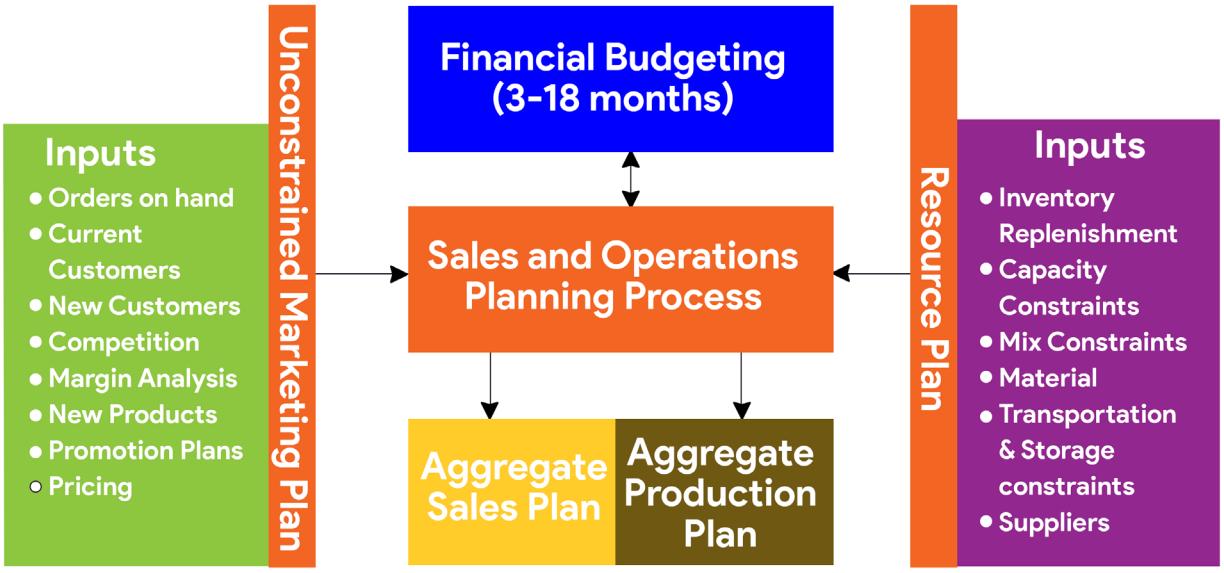



**Diagram 5.1 : S&OP Diagram**

Operations executives bring plans and knowledge concerning capacity constraints , inventory policies, suppliers capabilities, materials, availability and transportation and storage capacities.

Table 5.1 - Sales and Objectives : Balancing Objectives

| Sales | Operations |
|---|---|
| Aggregate forecasts | Detailed forecasts |
| Many product Variations | Few product variations |
| Rapid response | Long production runs |
| High service | Stable production schedules |
| Maximize revenue | Maximize output/minimize costs |

Table 5.1 - Finance is different from Operations in terms of objectives

| Finance | Operations |
|---|---|
| Maximize financial returns | Minimize costs |
| Reduce financial risk | Reduce variance |
| High returns on investment | Maintain uptime |
| Focus on customers with highest contribution margins | Focus on grouping orders together to enhance operational efficiency or to reduce setups |

## Example 1 : One-Number forecasting at Heinz

From 2002, the responsibility of forecasting resided with the marketing/brand management, which posed both benefits and challenges. In this approach each brand manager led initiatives to grow their business. However challenges included the presence of different motives underlying different forecasts. Brand management teams tended to be optimistic in forecasting, while sales management was conservative because of sales quotas. Finance typically added more optimism in forecasting, while production planning often applied a bit of conservatism in their desire to maintain low inventories. The functional groups estimates differed from each other because of their different assumptions and motivations. When shipments did not materialize as forecasted, everyone had their own explanation of why they missed the forecast.

Recently, Heinz required the forecasting department to begin reporting to the VP of supply chain and operations, who was tasked with responsibility to provide the essential link between the front end (marketing/sales) and the back end (supply

chain and operations) using the same forecast. Now one forecast drives both the front end business planning and the supply chain through constant communication and consensus meetings.

The forecasting enabled the entire organisation to plan based on the same assumptions, risks and upsides. In addition, it encouraged productive conversations around true planning for the first time. For instance, budgeting became less confusing because the samel volume forecast drove plans for marketing, sales, production, inventory, transit/warehousing, manufacturing/co-packing and ultimately financials. When spending increased and decreased, appropriate volume was either added or removed from the forecast. When large events at certain accounts shifted in execution timing, the associated volume was also moved. When promotions changed at the account level, deployment plans changed accordingly.

With this approach, potential issues surrounding supplies/suppliers and capacity at factories and warehouses surfaced much earlier than before. Most importantly, everyone was held accountable for the inputs and assumptions for the final forecast.

## Example 2 : Whirlpool and Lowe's Integrate their Planning

Lowe's and whirpool addressed only immediate merchandising and sales issues. Limited communication from time to time led to problems for the firms. Lowe had an issue when whirpool launched their new products, Lowe didn't know about the new products and there was already inventory which was not sold from the earlier versions and this costed both Lowe and whirpool in order to liquidate the appliances which was already in the stores and warehouses. A little trust and shared information saved both companies money.

Today both companies work on the integrated planning process. After developing demand planning Lowe and Whirlpool moved more towards supply planning. Lowe's initial focus on recognizing the capabilities and limitations of whirlpools manufacturing divisions. Both companies worked to develop an understanding of each other's target inventory levels and new product planning. Next, the ri supply chain organisations became actively involved with the sales and merchandising organisations. Structural demand and supply reviews created a single set of forecasts and sales plan for both companies. They focused collaboration on promotions, product launches and special event planning, creating an integrated promotional calendar for each product category.

The two companies developed a shared planning process built around joint business objective that emerged from each company's internal sales and operational planning process. This join planning helped Lowe's and Whirlpool to realize improvements in several key metrics. Until sales growth increased over a three year period by 12 percent, while overall inventory costs went down by 5 percent.

## S&OP Benefits

Organizations that have effective S&OP Process have experienced both the "hard" (quantifiable) and "soft" (qualitative) benefits

The hard benefits include :

- Improved forecast accuracy. Detailed discussions between representatives result in consensus forecast that is usually more accurate
- Higher customer service with lower finished goods inventory due to better forecasts and coordination of supply with demand.
- Stable Supply rates , resulting in higher productivity

The soft benefits include :

- Enhanced teamwork at both the executive and operations level
- Better decisions can be taken within less time and efforts
- Better alignment of operational , marketing and financial planning.
- Greater accountability of results
- Allows us to predict the potential future problems soon in order for us to plan for solution

## S&OP Process

The team first reviews prior plans and results so that lessons learned can be applied to new planning period. The supply and demand functional reviews produce a consensus forecast that guides the initial functional plan.

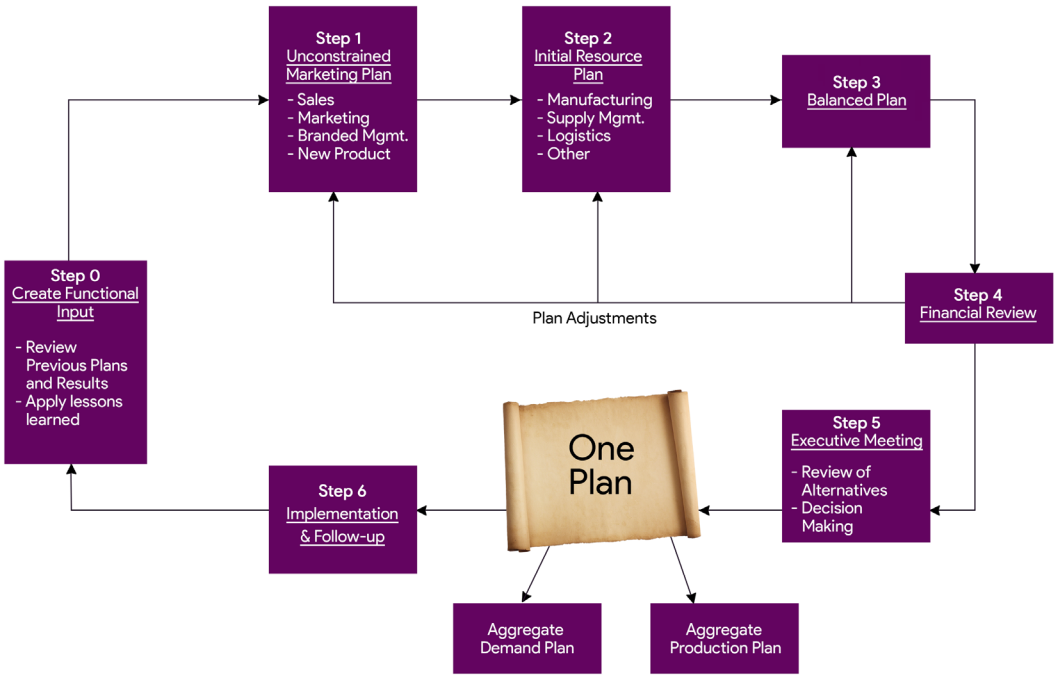



**Diagram 5.2 : The Sales and Operation Planning Process**

The S&OP team in reality is an iterative process , where the S&OP team develops consensus forecast and then each functional area develops its initial plans, the S&OP team then meets again to work out problems or potential inconsistencies .

S&OP is a dynamic process not a one time event. It is rare for an organization to establish the aggregate production plan at the beginning of the year and follow it blindly for the rest of the year. Most organizations has included the S&OP process as a part of the overall management process holding monthly, at least quarterly review meetings .Situations in the daily operations can change very quickly to unprecedented situations which can drastically change the aggregate production plan

Many companies incorporate rolling planning horizons , meaning that they replan each period for a given number of periods into the future. This approach updates the S&OP plan and aggregate production plan as conditions change.

Working collaboratively with customers and suppliers is one of the main ingredients of the successful s&op planning program. Bringing customers into the process through CPFR as discussed earlier in the report provides a much deeper insight into demand

Sharing aggregate production plans with they suppliers allows them to be better positioned to meet the requirements for materials , components and supplies. Leveraging the capabilities and influence of customers and suppliers explains the scope of potential improvements for the organization and for the supply chain .

Ultimately the output of the S&OP process is a balance in the demand plan and the aggregate production plan

## Aggregate Production Planning

The overall goal of aggregate production planning (also called aggregate capacity planning) is to set targets for inventory and various sources of capacity so that supply will match demand over the immediate time frame in the most efficient way possible .

The aggregate plan also takes into account other constraints formed by the company strategy and the often conflicting process of each functional area.

- ### Relevant Aggregate Planning Costs

  In order to carry out the relevant aggregate planning costs we need the identify and quantify the costs which are :

  1. **Inventory holding costs -** expenses related to cost of capital invested in inventory , insurance, storage, obsolescence and taxes
  2. **Regular production cost -** costs include the average labor costs to produce an aggregate unit and any benefits that are part of the pay package.
  3. **Overtime cost -** overtime may be scheduled for the labor force to gain additional output.
  4. **Hiring cost -** includes the cost of advertising for new workers, interviewing them, processing their applications and then training them. As temporary workers are hired only for a short duration of time , the hiring and firing costs of temporary workers may be less than a permanent workers.
  5. **Firing/layoff cost -** when the workforce level is decreased , their costs associated with either firing or laying of the workers . There are costs involved such as unemployment compensation or lump sum separation costs
     Backorder/lost sales cost - there could be costs involved with backorder a demand or lose the sales from that demand.
  6. **Subcontracting cost -** the company may choose to subcontract (outsource) production to another firm for a period of Time. There are costs involved over it as well because it is difficult to keep a track of the quality and delivery.

Often these costs may be difficult to precisely measure and estimates may be required. Few Firms either chose to leave the cost out as they are difficult to determine. They compare scenarios based on multiple criteria, making a judgement about the level of the removed factor as opposed to the cost impact of the factor. Usually these are costs of backorders and possible lost sales. There are always constraints on production plans and functional area requirement.

- **Aggregate Production Strategies**

  Solving aggregate planning problems involves formulates alternate production strategies for meeting demand and determining the costs and feasibility of those alternatives . Aggregate planning is not limited to only manufacturing firms. All organizations face a problem of matching their productive capacity to the patterns of demand.

  There are two "pure" strategies that form extreme alternatives of aggregate plans.

  **Level Production strategy -** the firm produces a constant rate over the year, building inventories in periods of low demand and depleting the inventory in a period of high demand.

  It is used when the costs of ramping production up and down are high and inventory costs are relatively low. If the firm's processes require highly skilled workers that are hard to find. The level production strategy provides a constant rate of output over the entire planning time period and requires no overtime , no changes in the workforce level and no subcontracting. The disadvantage of this is that it can cause inventory levels to be quite high following low demand seasons.

  **Chase strategy -** the production rate is changed in each period to match the amount of expected demand.

  It is used by firms that have high per unit inventory holding cost rates relative to their cost of changing the production rate. They may use part time seasonal workers who can hired during the high peak demands periods and laid off during low demand seasons.

  Most service industries use a chase strategy because they don't have the option of building the inventory of their product . Many firms in the high technology industries follow a chase strategy because of the product changes occur so rapidly that inventory held over substantial amount of time can be easily be rendered obsolete. This strategy can be executed by adjusting labor, subcontracting or some mixture of the two.

  In reality, most firms typically use a mixed or hybrid strategy.

## Example 3 : Cannon struggles to shrink level of digital camera inventory

The global economy downturn in 2008 brought down with its prices for the digital camera boom. Digital camera makers had to cut the cost in order to reduce the inventory of their excess stock. The last year which is 2007 sales growth was at 27% high and depending on the projections of the higher growth, the companies have manufactured more of them for the christmas. This risk was taken based on the sales which was skyrocketing from the previous years. This resulted in the higher supply of inventory.Even cannon efficient and flexible supply chain management failed to adjust production quickly to match the rapid collapse of final demand, allowing excessive output to build up.

This cost the company. Contract workers at the company manufacturing unit Oita Prefecture were laid off. Cannon contract manufacturers had to lay of 1100 jobs when its order was slashed. Therefore it is necessary to mathematically model the scenario using the hybrid strategy which will help the organisation to be flexible.

- **Hybrid strategies**
  Such a strategy includes some elements of both level and chase strategies. This is achieved by the company might use inventory to help smooth production during part of the season, and then workforce changes, including overtime and temporary workers, to supplement production during another part of the season.

  Regardless of the chosen strategy, aggregate production plans need to be revisited when circumstances change.

## Creating an Aggregate Production Plan

- **Level Production Plan**
  A level production plan sets production at the average rate of demand after adjusting for beginning inventory and desired ending inventory.

$$P = \frac{\overline{X}\, Di + El - Bl}{N}$$

  Where,
  P = level production rate
  Di = demand in period i
  EI = desired level of ending inventory
  BI = beginning inventory
  N = number of planning periods

- **Chase Plans**
  The objective is to match production in each period to the demand in that period, thus avoiding the need

to hold the inventory : Three options to accomplish this objective.

1. Produce all units internally by hiring workers in high demand months and firing/laying off workers in low demand months.
2. Produce internally the quantity required to meet demand in the lowest-demanded month and use overtime production to meet demand in other months.
3. Produce internally the quantity required to meet demand in the lowest demand month and use subcontracting to meet demand in other months.

- **Hybrid Plans**
  The actual production plan combines some aspects of level production and building inventory with aspects of chase, or varying the production rate during each period to match production and demand.

- **Comparing aggregate Production Plans**
  A manager could easily set up a spreadsheet on a personal computer in order to quickly evaluate many different scenarios. Costs such as overtime costs, subcontracting costs, inventory costs, hire costs, fire/lay off costs could be all put across in one single spreadsheet. If used interactively, this methodology can be effective at generating a solution that all major functions can agree on, and the interactive process allows managers to see the effect of changes as they are made, which can uncover unrealistic cost assumptions and unworkable situations. This is especially important when all the constraints have not been identified upfront. Dialogue between managers and eventual agreement on a good production plan could easily be better than optimal one that is forced on everyone.

  Sophisticated modeling techniques such as linear programming, integer programming and others can be applied to the aggregate production planning . These techniques require precise specification of assumptions, constraints, costs, and objectives in a mathematical formal.

- **Aggregate Planning for Service Industries**

S&OP and aggregate planning are just as critical in service industries as in manufacturing. In some cases such planning is even more critical because there is no ability to build inventory in anticipation of demand. When supply and demand do not match , the impact is almost always on Human Resources

**Yield Management -** It is the process that adjusts prices as demand for service occurs . The purpose of the yield management is to shape demand in a way that yields greater revenues or profits . Yield management can involve very sophisticated mathematical models that simulate customer behaviors under different scenarios. Complex computer programs have been developed in those industries to

continuously analyze demand versus available capacity and make price adjustments.

Effective yield management requires extensive analysis of past demand so that typical demand patterns and trends are clear. It also requires continuous tracking of actual demand for the service.

Ultimately most service businesses have to develop aggregate plans based on the human resource requirements . The process is not greatly different from that already discussed , except there is no inventory to be considered .Instead demand for services is often stated in terms of the amount of service labour required rather than the amount of product required.

## Enterprise Resource Planning

An ERP system consolidates all the business planning systems and related data throughout a company , so the planning processes across all business functions can be integrated and consistently applied . The goal of the ERP systems is to allow business processes to function seamlessly and in union . The improved coordination of planning from ERP takes efficiency to greater heights. SAP and Oracle are leading providers of the ERP software.

DRP, MRP and CRP are integral parts of the enterprise resource planning (ERP) systems

DRP also known is distribution requirements planning is the determination of replenishment and position of finished goods in the distribution network . Distribution network scan be very complex with multiple levels of distribution centers and thousands of retailers . Thus planning and coordination across the supply chain be difficult . The output of DRP is used for input into operations and logistics planning processes.

MRP also known as materials requirement planning system used to ensure the right quantities of materials are available when needed for production. It determines how much and when to produce using the time phased schedule that is based on lead time.

CRP also known as Capacity Requirement Planning determines if all the work centers involved have the capacity to implement the MRP. The CRP process uses planned order releases and scheduled receipts to estimate work center loads. A load profile compares weekly loads needs against a profile of actual capacity

### Example 4 : Yield Management in the Hotel Industry

A profitable yield management strategy involves exploiting the best (and diminishing the least efficient) aspects of a hotels daily operations. Wholesale cost cutting rarely proves effective because there aren't many viable areas, depending on the hotel's brand and service level in which to make cuts; you can't close down one day a week to save energy and maintenance, you can't shut down the pool just because only a handful of guests are there to swim and you can't leave the front desk unmanned to save the cost of a shift.

Instead leveraging some routine costs can be useful in bostering hotel revenue. For example costs associated with a hotel's breakfast buffet, including food preparation and waste disposal, will exist whether the hotel is fully or sparsely occupied on any given day; the table could be all laid out but with too few guests to partake of what's offered. A "free breakfast" offering during the slow periods can encourage more guests to stay at the hotel, improving overall revenue with only a marginal effect on food and beverage costs. Likewise a complimentary phone and internet use are swiftly becoming the norm for negotiated corporate rates, Such value added amenities can prove an essential lure in capturing demand.

## Advanced Planning and Scheduling (APS)

Conventional requirements planning systems were sequential and iterative in nature, and today many still are. Imagine a planning process that simultaneously considers material requirements along with resource capacity constraints. In this process a plan could be developed that optimizes all related costs, for example inventory, labor, capital, and other costs. This level of joint optimization is the goal of advance planning and scheduling (APS) systems that are often included in ERP systems. APS systems use the same fundamental explosion logic of MRP. However they integrate materials and capacity planning into one system. APS is possible because of vast improvements in computing power coupled with the development of sophisticated mathematical algorithms that help to solve very complex scheduling problems

Requirements and resource planning systems have achieved a high level of acceptance because of the important advantages that they offer to firm. As multiple firm work together to adopt and share compatible planning systems, the supply chain can experience significant systems. Planning systems that are extended across supply chain partners provide greater visibility into current status and into plans for the future. By anticipating supply and demand conditions into the future. APS systems help managers to identify and avoid problems and quickly evaluate alternatives. Supply chain partners can jointly plan their operations using what-if analyses.  They evaluate different scenarios of changes in customer demand and material delays. This analysis helps supply chain partners to identify options and create contingency plans.

## Example 5: ERP Performance at Elizabeth Arden Red Door Spas

ERP systems are not just for manufacturing . Elizabeth Arden Red Door Spas has 30 locations designed to provide the ultimate in pampering through salon and spa services. The management team was planning to add locations both within the United States and internationally. However, its human resources, finance, logistics systems were not integrated, making decision making difficult. Recently, to give its legacy business systems with an ERP System from SAP. The systems made it easier to track orders. Inventory at its salons and distribution caner dropped, reduced costs. Employees could spend more time with customers and less time on administrative tasks. More importantly, the ERP system provided more consistent data that could be used for making better business decisions.

# PART 6

## Quality Improvements Tools

## Quality Improvements Tools

Quality management tools male managers and employees better problem solvers by giving them the tools and produce to measure the improvement process, to identify potential problems and to describe these problems to others. These tools can help managers determine whether processes are under control or whether they are capable of meeting certain performance specifications needed to make products acceptable to customers.

The major goal of quality improvement is to move from uncovering symptoms of problems to determining the underlying root causes of problems in a structured and logical manner. In this process , quality management decisions should be based on the data whenever possible . Data falls into two categories , variable data and attribute data.

Variable data measure quantifiable conditions such as speed , length , weight , temperature , density and so forth.
Attribute data measure qualitative characteristics of a process output (pass/fail, go/no go, good/bad).

All variable data can be transformed into attribute data. However it is not possible to transform attribute data into variable data .

Few of the quality improvement tools and their functionalities are

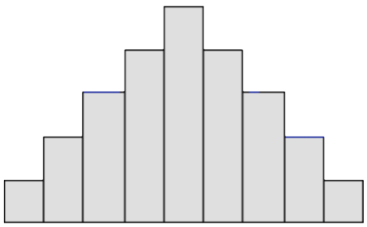
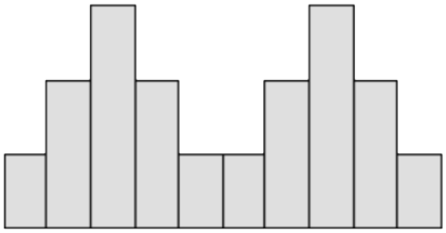
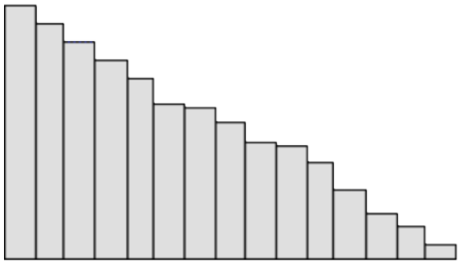
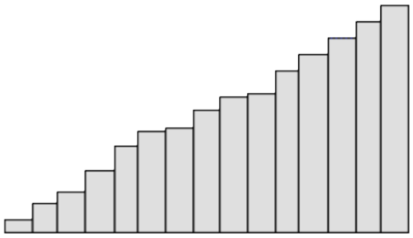
| Quality Tools | Typical Usage |
|---|---|
| Histograms | To uncover underlying patterns (range and frequency) in data variability. |
| Cause and Effect Analysis | To uncover possible contributors to an observed problem; to facilitate group brainstorming. |
| Check Sheets | To identify the frequency and location of problem causes. |
| Pareto Analysis | To identify the most critical (relatively frequent) causes of problems. |
| Scatter Diagrams | To determine if two variables are related to each other (do the two variables move together in some predictable manner). |
| Process Flow Analysis | To graphically display and analyze the steps in the process. |
| Process Capability Analysis | To predict the conformance quality of a product by comparing its specification range to teh range of its process variability. |
| Process Control Charts | To monitor process outputs and determine whether a process is operating according to normal expected time. |
| Taguchi Method/Design of Experiments | To evaluate and understand the effects of different factors on process outputs. |

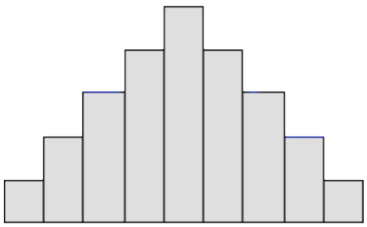
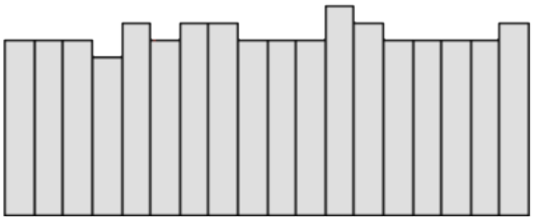
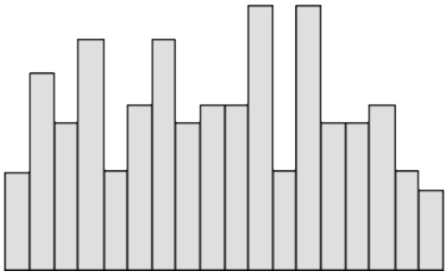
**Table 6.1 : Quality Improvement Tools**

1. **Histograms :** Variance exists in every activity or process. A histogram graphically displays a distribution of values in data and one variable to show the extent and type of variance . To create histogram , one needs at least 30 observe actions but more are better. Also the analyst must determine the number of ranges or categories for grouping the data.

Histograms help problem solvers recognize and understand three critical traits and distributions:

- **Center:** the theoretical or desired mean should fall at the center of the distribution . Any gap between the observed mean and XX may indicate bias
- **Width:** the range (the difference between eh highest and lowest values) is shown graphically by the histogram. The width indicates the predictability of the process (I.e the wider the distribution, the less predictable it is )
- **Shape:** The overall shape of a distribution can indicate problems in the data or influence on the overall distribution.

| | |
|---|---|
|  | **Bell Shaped :** this is the typical or normal distribution that we expect to see when dealing with variable data. It is centered and symmetrical about the mean.<br><br>This can be used as a reference baseline to the rest of the histogram models. |
|  | **Double or Twin Peaked :** This indicated that the two normal distributions have been combined i.e they are from two different systems. If this occurs then we should separate and analyze it. |
|  | **Skewed Right :** The distribution skewed to the right is said to be positively skewed. This typically indicating that there is restraining the process on one side of the distribution. A skewed distribution can result when data is gathered from a system with has a boundary such as zero. In other words, all the collected data has values greater than zero. |
|  | **Skewed Left :** The distribution skewed to the Left is said to be negatively skewed.This typically indicating that there is restraining the process on one side of the distribution.A skewed distribution can result when data is gathered from a system with a boundary such as 100. In other words, all the collected data has values less than 100. |

| | |
|---|---|
|  | **Bell Shaped :** this is the typical or normal distribution that we expect to see when dealing with variable data. It is centered and symmetrical about the mean.<br><br>This can be used as a reference baseline to the rest of the histogram models. |
|  | **Uniform or Plateau :** This results of combining multiple data sets, where the data sets are moving.If the histogram has this shape, check to see if several sources of variation have been combined. If so, analyze them separately. If multiple sources of variation do not seem to be the cause of this pattern, different groupings can be tried to see if a more useful pattern results. |
|  | **Random or Comb :** If the histogram has this shape, check to see if several sources of variation have been combined. If so, analyze them separately. If multiple sources of variation do not seem to be the cause of this pattern, different groupings can be tried to see if a more useful pattern results. Typically this means there are more errors in the data collection , rounding errors or poor grouping of data into categories. |

2. **Cause and Effect Diagrams :** The cause and effect diagram (CED) examines complex interrelationships and identifies the root causes (which are often hidden) of problems and links them to the symptoms (which are often very visible). The CED is also known as fishbone diagram or an Ishikawa chart.

   In practice, CED's offers users several important advantages :

   - They are useful brainstorming tools. They are best developed by a group of people who represent a variety of perspectives
   - The discourage the presence of management myopia - CED's help managers to seek all the potential causes, rather than limiting their attention to only a few.
   - They help to uncover the logic chain that leads from the root causes to the effects, thus showing how the various factors interact with each other to cause the observed problems.

The process of building the diagram consist of the following steps :

- Identify the problem to examine - State the symptom or the effect (outcome) that must be explained in the form of variance statement)
- Identify the major categories of causes - Identify the major categories of potential causes that could contribute to the effect .
- Identify more specific causes - One each branch , place smaller branches to represent detailed causes that could contribute to primary categories of causes.
- Circle likely causes - After the diagram has been developed to show all potential causes, review all of the causes and circle the most likely ones. Further analysis and data collection can focus on the causes.
- Verify the causes - After identifying the most likely causes , use the other tools to ensure they really are the root cause of the problem.

**Table 6.1 : Commonly used categories of Causes**

| Minimum Set | 6 Ms (Used in Manufacturing) | 7 Ps (Used in service industry) | 5 Ss (Used in service industry) |
|---|---|---|---|
| People | Machine (Technology) | Product = Service | Surroundings |
| Machine/Equipment | Method (process) | Price | Supplies |
| Methods/Processes | Material | Place | Systems |
| Material | Manpower/Mind Power | Promotion | Skills |
| | Measurement (inspection) | People/Personnel | Safety |
| | Mother Nature (Environment) | Process | |
| | | Physical Evidence | |

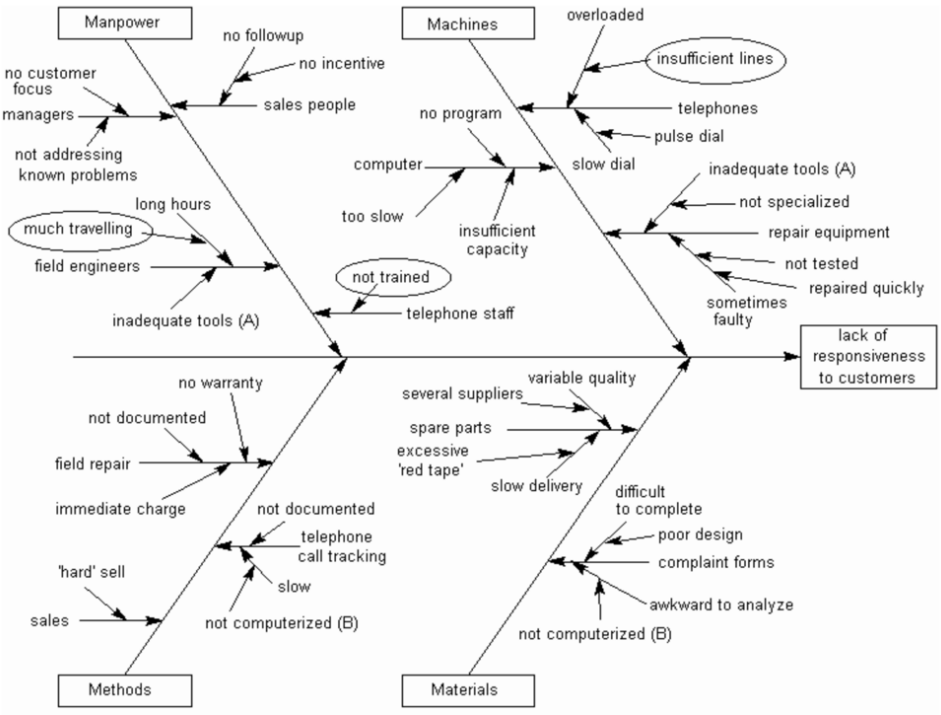



**Diagram 6.1 : Example of Cause and Effect Diagram**

**Check Sheets :** A check sheet is simple tool used to collect, organize and display data to reveal patterns. An attribute check sheet consists of categories such as problem types , problem categories, or time. The categories could come from a cause and effect analysis. These categories typically resent factors that are seen as playing an important role in explaining what is happening. The goal of an analyst in collecting this data by category is to determine if there is a tendency for the data to be systematically associated with certain categories.

**Source of Incoming Model Home Traffic**
**Check Sheet**

| | Monday | Tuesday | Wednesday | Thursday | Friday | Total |
|---|---|---|---|---|---|---|
| Daily Newspaper Ads | 𝍸 \|\| | \|\|\|\| | 𝍸 | \|\|\| | 𝍸 | 24 |
| Weekly Newspaper Ads | \|\|\| | | \|\| | \| | \|\| | 8 |
| Website | \|\|\| | 𝍸 | 𝍸 \| | \|\|\|\| | \|\| | 20 |
| Road Signage | | \|\| | | \| | | 3 |
| Referral | \| | | | | \| | 2 |
| Total | 14 | 11 | 13 | 9 | 10 | 57 |

**Diagram 6.2 : Example of Check Sheet**

**Pareto Analysis :** Pareto analysis sets priorities for action based on the assumption that roughly 80 percent of problems typically result from the 20 percent of possible causes. Thus not all possible causes of problems are equally important. Pareto analysis identifies the most critical (most frequent) causes to problems so that improvement efforts can be focused where the investment of time, effort and money will yield the largest return

Pareto analysis consists of a four step procedure

1. Identify categories about which to collect information
2. Gather the data and calculate the frequency of observations in each category for an appropriate time period
3. Sort the categories in descending order based on their percentages
4. Present the data graphically and identify the vital few categories that account for most of the variation

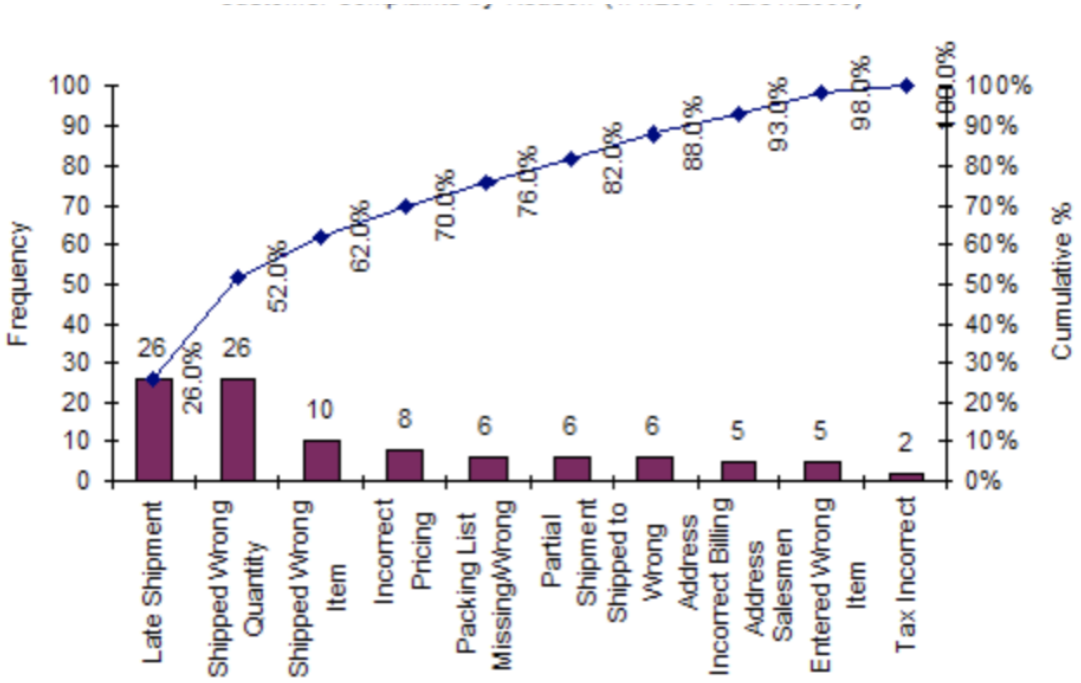



**Diagram 6.3 : Example of Pareto Analysis showing the last two issues accounting for 52% percent of the issues for the reason of customer complaints.**

**Scatter Diagram :** Scatter diagram graphically illustrates data points that indicate the relationship between a pair of variables, such as how the number of defects per batch relates to changes in the speed of the production line or how the production time per unit relates to hours of training. This information can help to confirm or deny hypothetical causes of observed effects.

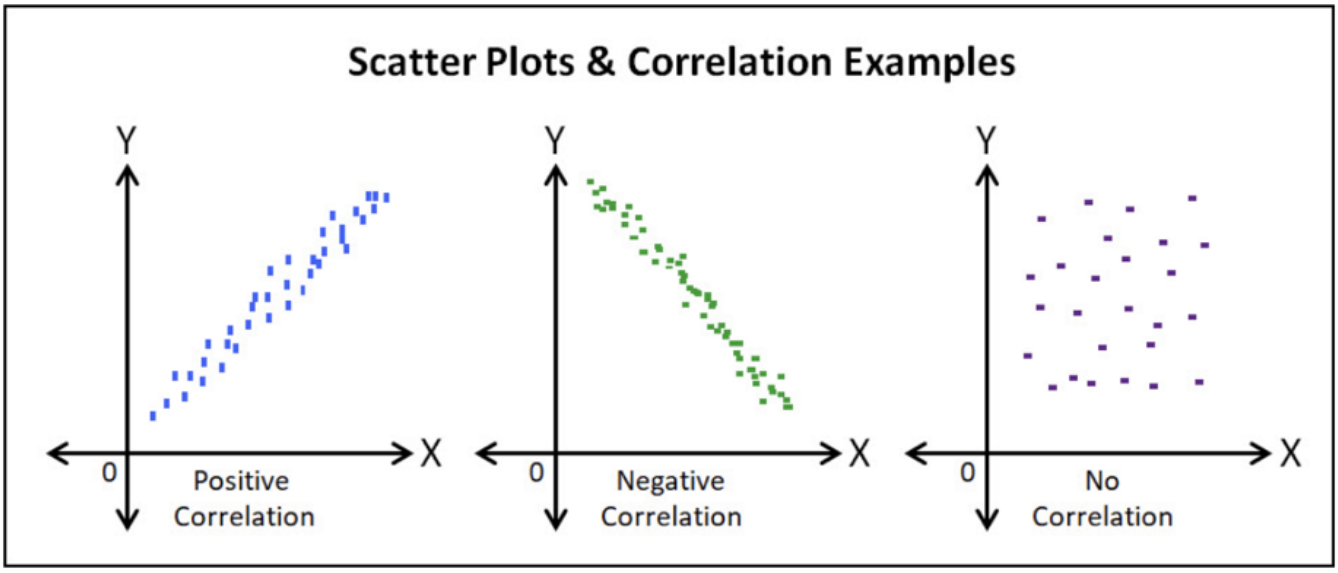



**Diagram 6.4: Example of Scatter Plots and how its correlation Examples**

**Process Flow Diagram :** A process flow diagram uses symbols to represent the actives and inter relationships contained in an operating process. By diagramming a process, you can study its details and uncover potential causes of variance and opportunities for improvement.

## Process Capability Analysis ($C_p$ and $C_{pk}$)

It is a tool for assessing the ability of a process to consistently meet or exceed a products design specifications.

Mathematically process capability is represented by the capability index, $C_p$ (and its associate measure, $C_{pk}$). The $C_p$ is essentially the ratio of the specifications width to the process width. It is calculated as follows :

$$Cp = \frac{\text{Specification Width}}{\text{Process Width}} = \frac{\text{S}}{\text{P}}$$

Where
Symbol 1 = $\sigma$

$C_p$k Improving on the $C_p$ statistic

Mathematically he $C_p$ & $C_{pk}$ can be written as

$$Cp = \frac{\text{S}}{\text{P}} = \frac{(\text{USL} - \text{LSL})}{6\sigma}$$

Where :
S = Upper specification limit - Lower Specification limit
P = 6 Σ
Σ = Standard deviation of process output

P is expressed as a function of Σ because most process output distribution are open ended; that it some probability, albeit small, that any output value could be produced. By convention managers in the past have chosen to set P = 6Σ because 6 standard deviations define a range covers about 99.7 percent of the output for the processes that vary according to a normal distribution. Thus a $C_p$ value less than would indicate that more than 0.3 percent of product will not meet the design specifications

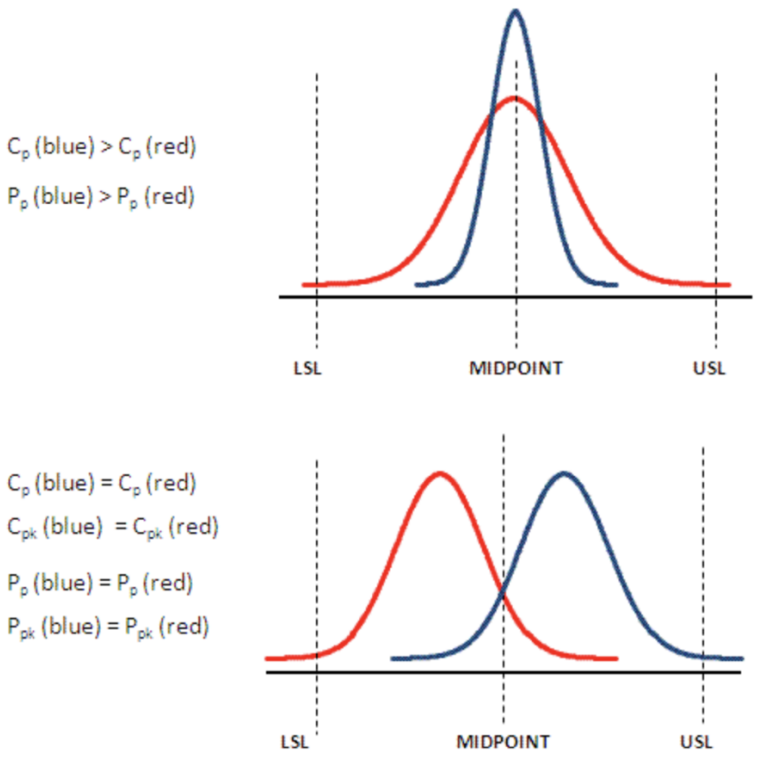



**Diagram 6.5 : Relationship of capability indices**

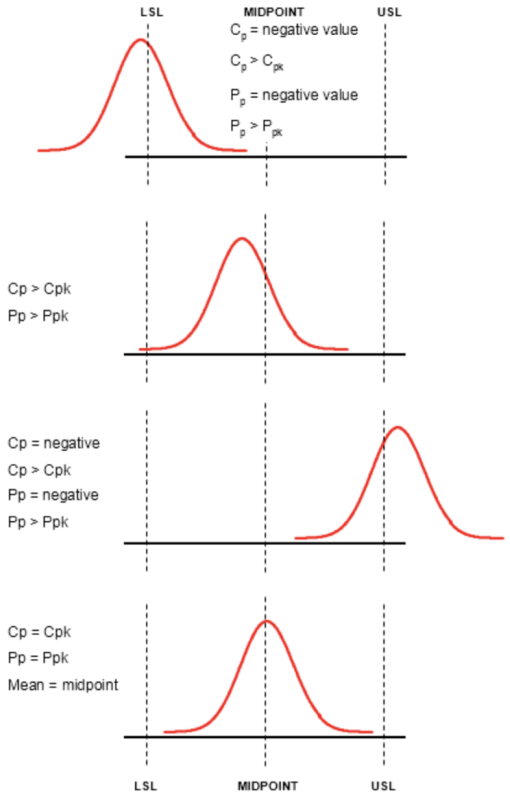



**Diagram 6.6 : Other additional relationship indices**

### $C_{pk}$ improving on the $C_p$ statistic

The $C_p$ value effectively measures process capability only when a process is centered; that is when the center of tis output distribution is the same as the center of the product specifications range.

Mathematically, the $C_p$ and $C_{pk}$ can be written as follows :

$$Cp = \frac{\mathrm{S}}{\mathrm{P}} = \frac{(\mathrm{USL} - \mathrm{LSL})}{6\sigma}$$

$$K = \frac{|\mathrm{D} - \overline{X}|}{\frac{\mathrm{S}}{2}}$$

$$Cpk = (1 - \mathrm{K}) \times Cp$$

Where :

USL = upper specification limit

LSL = lower specification limit

D = Center for product specification range = (USL + LSL)/2

$\overline{\mathrm{X}}$ = Mean of the process output distribution

K = Adjustment for differences between the specification center and the process mean

The $C_{pk}$ and $C_p$ are almost the same except for the correction term, (1 - K). The calculation of K involves a new parameter D, which is the design center of the specification width S. D is the target value for performance data, while $\overline{\mathrm{X}}$ is the process average. When the D equals $\overline{\mathrm{X}}$ then $C_{pk}$ is identical to $C_p$.

There is another way of thinking about these two measures , $C_p$ deals with the extent to which the process is consistent, while $C_{pk}$ looks at the extent to which the process is centered.

## Alternative method for computing $C_{pk}$

The $C_{pk}$ formal presented in the preceding section emphasizes the need to adjust $C_p$ for the difference between the process mean and center of the product specification limits. $C_p$ and $C_{pk}$ can also be calculated using the following formula.

$C_p$ = (USL - LSL)/6Σ

$C_{pk} = \min [(USL - \overline{X}) / 3 * \Sigma , (\overline{X} - LSL) / 3 * \Sigma$

The alternative calculations for $C_{pk}$ are frequently found in discussions of Six Sigma. Either is acceptable.

## Process Control Charts

It is a statistical tool used to monitor a process output to detect significant changes. Once a process is determined to be capable, it should be monitored over time to ensure that it remains stable. Sometimes things can change that the range of process output changes, or the mean (i.e centering of the process) shifts. The terms statistical process control (SPC) and the process control charts are often used synonymously.

A control chart plots values for samples for process output collected over time . The plotted outputs are compared to a set of limits for the upper and lower boundaries of the process width. As defined by a confidence interval (usually 99 percent or 3 Σ). Any output sample value that lies between the upper and lower limits is within the expected normal random variation of the process . However points that fall outside these limits are not likely to have occurred by chance, suggesting that the process may have changed. Thus, process control charts identify when a process has deviated from its normal operations (I.e. when it is "out of control:). Such a change prompts the process operator to stop, investigate and correct the process.

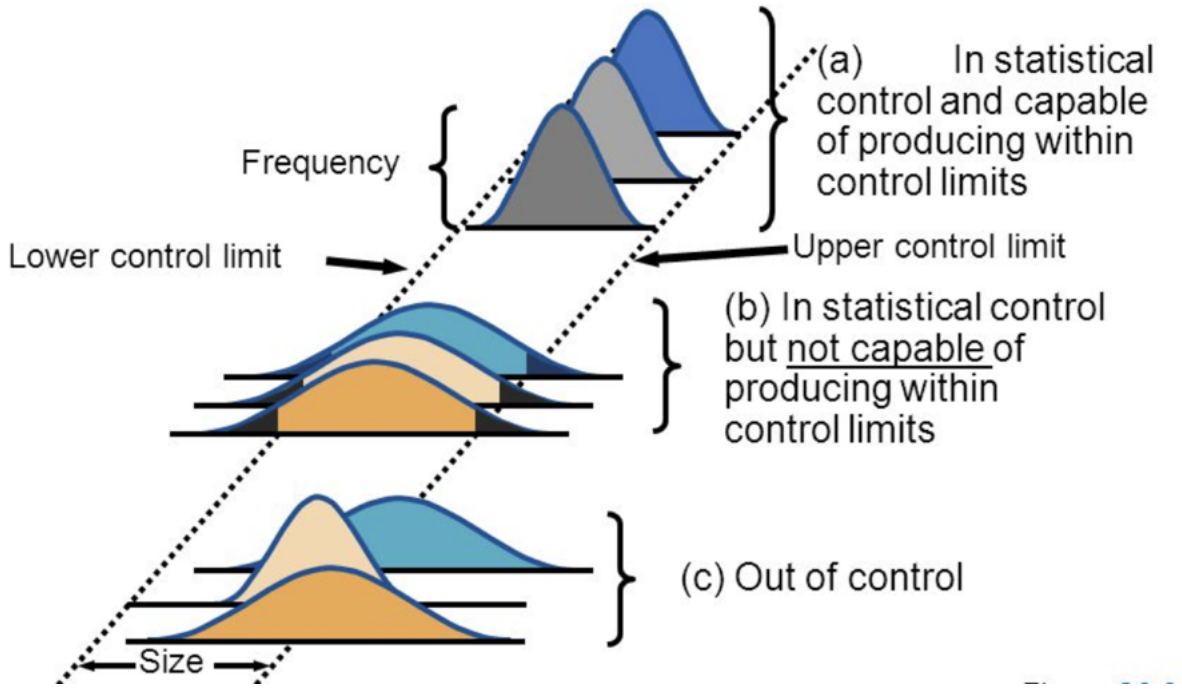



**Diagram 6.7 : Explanation to Process control graphs.**

Process control charts are similar to process capability studies ($C_p$ and $C_{pk}$) in that both tools evaluate the variability of processes. However, there are some important differences between these two tools. Process control charts are used to regularly monitor the output of a process to ensure that output lies within the expected variation limits of the process.

Process control compares summary statistics (Eg. Mean and Range) for samples of output against predetermined process limits.

Process capability studies on the other Hand evaluate the extent to which process output lies within design specification limits. It studies the variation in a large population of output, rather than the variation of sample means and ranges. It is important to understand that the use of process control charts only ensures that the process is operating normally , it does not ensure that product output meets the design specifications. Evaluating consistency with design specifications is the purpose of a process capability study.

There are 5 common types of control charts , listed in the table below

| Type of Data | Control Chart Used | Types of Data |
|---|---|---|
| Variables - Continuous/Non Discrete | $\overline{X}$ - R | Measurement (inches,mm) volume product weight power consumed |
| Attributes - Discrete | p (probability of defect) | Number of defects |
| Attributes | p | Fraction defective |
| Attributes | U | Number of pin holes in pieces of plated sheet, differing in area (area/volume not fixed) |
| Attributes | C | Number of pin holes in a specified area (area is fixed) |

## Taguchi Methods/ Design of Experiments

Professor Genichi Taguchi , director of Japanese academy of quality and four time recipient of the Deming Prize. He recognized that managers could eliminate the need for mass inspection by building quality into both the products and process at the design stage.

Taguchi developed a straightforward , well integrated system (now called the Taguchi Methods) for improving the design of both a product and the process used to produce it . The objective of this system is to identify easily controllable factors and their settings that can minimize variation in product features while keeping the mean values (or "response") of these features on target. By focusing on both the product and the process and using well developed designs, managers, can develop products and processes that are properly centered and that performance distributions with reduced spread.

### Other quality control tools used in the market include

- Acceptance Sampling
- Operating characteristics curves
- Taguchi loss functions
- CTQ tree (critical to quality - a tool used to decompose broad customer requirements into more easily quantified requirements)

Quality storyboards -(a visual method for displaying a quality control story that helps the personal go from plan and problem definition to actions)

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