

# Supply Chain and Operations Management Glossary

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This glossary was originally compiled in conjunction with a course on Logistics and Supply Chain Management at the University of Chicago.

Entries tend to be arranged according to their abbreviation. Thus, Bill-Of-Material is defined under BOM. The reasoning is that it is easier to deduce the abbreviation from a phrase, than deduce the phrase from the abbreviation.

**3PL** (Third Party Logistics): The use of an outside party to perform some part of the logistics function, typically trucking or warehousing. It is appropriate if there are economies of scale in the logistics function.

**ABC Analysis:** Partition of products into three groups according to their yearly dollar volume. A typical result is that 30% of the products (the *A*'s) comprise 70% of the volume. More sophisticated control procedures are appropriate for class *A* products. Very simple, cheap methods suffice for managing class *C* items. This is similar to Pareto analysis.

**ABC** (Activity Based Costing): An accounting method that attempts to closely associate costs, particularly indirect costs, with the activities that generate the costs. This is sometimes also called transaction-based costing. The most crucial aspect of ABC is identifying the "cost drivers" (e.g., number of stops on a delivery route, number of miles on a delivery route, number of pallets delivered, etc.) and then deducing the cost rate to apply to each activity.

**A.C. Nielsen:** A Chicago based supplier of industry sales data for consumer products (e.g., supermarkets). These data are obtained from sources such as cash register scanners. Another supplier of such data is IRI.

**Acres:** unit of land measure= 4840 square yards=0.4049 hectares. 640 acres=1 square mile. See SI units.

**AGV** (Automatic Guided Vehicle): a driverless vehicle used in warehouses and factories to move material. It can replace forklifts for some tasks. Usually the material to be moved must be on a standard pallet. In its most automated form, when a pallet is to be moved to a new location, the AGV system is informed of the origin and the destination of the desired movement. An AGV will pick up the pallet, navigate through the factory following either wires or magnets buried in the floor or laser beams. An AGV may be managed by a WMS.

**AICPA** (American Institute of Certified Public Accountants).

**ANSI** (American National Standards Institute): see <http://www.ansi.org> or <http://www.nssn.org>. This is an agency for publishing U.S. and international standards.

**AP** (Accounts Payable): List of amounts due to our suppliers. Software system for deciding when to pay which bills based upon discounts and penalties that depend upon when paid.

**AR** (Accounts Receivable): List of amounts due to us by customer. Software system for monitoring and updating amounts due and highlighting accounts according to their need for attention (e.g., more than 30 days past due, more than 60 days past due, etc).

**ASA** (Average Speed of Answer): A standard measure of service quality in in-bound call centers. A typical target is 20 seconds or less. In the US, the time between "ring" tones is six seconds, so this corresponds to a little over three rings.

**ASN** (Advance Shipping Notice): An electronic message from the shipper (or supplier or sender) to the customer (or receiver) that the product has been shipped and is expected to arrive during a specified time interval.

**ASP (Application Service Provider):** A firm that provides both computing power and business software to businesses via the web, somewhat similar to timesharing firms in the 1970's. A business that uses an ASP can be billed per transaction, so that a small firm might be able to use a powerful piece of software without having to pay a high fixed license fee for it. Another advantage is that the details of software maintenance and upgrades are invisible to the user. A risk in using an ASP is that the ASP may fail either physically or financially, in which case the business that uses it may have less recourse than if its information processing was done in-house.

**AS/RS:** Automated storage and retrieval system. The benefits of an AS/RS are typically: higher pick rates per person and greater storage density of products. The greater density is because items may be stored higher.

**ATP (Available To Promise):** Amount of product that a facility can promise to deliver quickly because it has a) the required product and components on hand, b) not promised already to some other customer, and c) has production capacity to assemble the product, not already scheduled for production of other products for other customers.

**Attributes sampling:** In quality assurance, sampling in which a yes/no attribute is measured (e.g., defective or not). In contrast, see variables sampling.

**AVI (Automatic Vehicle Identification):** A system in which participating vehicles (e.g., trucks) carry a transponder that may be queried by a reader (e.g., at a weight scale, a toll booth, or at port of entry at a state border). The transponder, if it recognizes the device or system sending the query, will respond with its identification code. This kind of system is also used in automobile toll collection. The identification code contains information about the type of vehicle, such as the number of axles. The roadway may have additional sensors to count the number of axles and/or estimate the length of the vehicle and check if it matches the vehicle description in the code sent by the transponder.

**AVL (Approved Vendor List):** For each SKU that we might buy, a list of vendors who have been approved to supply this SKU (e.g., on the basis of quality, price, delivery time).

**B2B:** Business to Business. This is a transaction between two businesses.

**B2C:** Business to Consumer. This is a transaction between a business and a consumer.

**Backhaul:** A return trip, carrying goods perhaps at a lower rate, after making the primary delivery. See also deadhead.

**Backlog:** very similar to back order. Product ordered by customer but not yet delivered.

**Back order:** unsatisfied product demand for which customer is willing to wait for shipment later, rather than cancel the order.

**Backup Agreement:** A purchasing arrangement between a supplier and a retailer that bundles the purchase of given number of nonreturnable units, with the option to buy a given number of additional units for quick delivery at a specified price. For example, the retailer might purchase outright 80 units at \$150 each, bundled with 20 options at \$15 per option, to purchase an additional 20 units at \$140 each. Compared to a conventional agreement, a backup agreement spreads the forecasting risk between the supplier and the retailer. A conventional agreement that allows full refund of unsold units puts all the forecasting risk on the supplier (and the retailer will tend to order too much). A conventional agreement with no refunds puts all the forecasting risk on the retailer (and the retailer will tend to order too little).

**Bait-and-switch:** A situation where a vendor advertises two types of products, a cheap one, Type *Y*, and a more expensive one Type *A*. There are two classes of customers: Class *II* customers are only willing to buy product *Y*, whereas class *I* customers prefer product *Y* but are willing to buy product *A* if *Y* is out of stock. An interesting inventory management problem is how many units of product *Y* to stock. If a small quantity of *Y* is stocked, then class *I* customers may arrive hoping to buy *Y* but end up buying the more expensive (and profitable to the vendor) type *A* product. This is very similar to revenue management as practiced in the airlines. Ethics/long term customer good will suggests that the vendor should be clear in the advertising of *Y* that "limited quantities available, no rain checks".

**Balanced Scorecard:** Traditional accounting measures are mainly designed for measuring performance as seen by the stockholders. Robert Kaplan of Harvard Business School popularized an extension of accounting measures, consisting essentially of the following steps: 1) Identify the company's stakeholders (e.g., customers, employees, communities in which the company operates, stockholders). 2) For each stakeholder, identify metrics for the company's performance. E.g., order fill rates, product return rates; wage rates, employee turnover; charitable gifts, pollution levels; stock price. 3) Measure and report the company's performance on each of these measures.

**Baldrige Award:** An award that recognizes quality achievement by U.S. organizations, see <http://www.quality.nist.gov>. It is named after former Commerce Secretary, Malcolm Baldrige, who was killed in a rodeo accident in 1987. Annual awards may be given in four categories: manufacturing, service, small business, and education/health services.

**Balking:** The action of an arriving customer in a service system to not join a waiting queue because the queue is too long. This results in a lost sale. Contrast with reneging.

**Bar code:** A machine readable marking on a product or box. It typically contains 10 to 12 digits of information about the contents of the box. A major manufacturer of barcode printers, Zebra Technologies, takes its name from the appearance of these bar codes. More recent two-dimensional codes may contain as much as 100 characters. See also UPC, RFID. The general public is familiar with bar codes for the use in checkout of purchases at a cash register. Bar codes are also very important in warehouses/DC's in that they facilitate automated sorting.

**Barge:** a vessel used mainly in inland water transportation. It typically is not powered. A set of barges, perhaps a half dozen or more, may be grouped into a "tow" which is propelled by a tugboat. The advantage of a barge is that, like a trailer in a tractor-trailer combination, it can be left at a loading or unloading point to be loaded or unloaded over a period of hours or days while the tugboat moves on to other activities.

**Base stock policy:** An inventory policy whereby, whenever a demand occurs, an order is immediately made to replace the amount sold. It is a  $Q,r$  policy with  $Q = 1$ . See JIT.

**Bathtub curve:** A typical shape for the failure rate curve for many pieces of equipment (i.e., the conditional probability of failure in the next hour) is to start high due to the "birth defects" new equipment may have, decrease to a low fairly constant rate for a long period of time, and then increase again as the equipment reaches "old age". See also failure rate curve, MTBF, IFR, and DFR.

**Bay:** an open area in a building such as a warehouse, unimpeded by pillars. Thus, a building with  $n$  rows of interior pillars would have  $n+1$  bays. If an overhead crane is used for moving material, it can usually move only within one bay.

**Beer game:** A business game composed of a four level supply chain. Early members of the chain (e.g., the manufacturer) do not see final demand directly, but only indirectly via the information, mainly in the form of orders received from their immediate downstream customer. Small fluctuations in retail demand typically cause big fluctuations in demand seen by the manufacturer, illustrating the bull-whip effect.

**Bill of Lading:** A binding legal contract between a shipper and a carrier for each load picked up by the carrier from the shipper. It lists the items picked up and the address to which they are to be delivered. It is the shipper's receipt from the carrier.

**Binomial distribution:** Suppose your product is in use by  $n$  customers. On any given day, any given customer will generate a service call request with probability  $p$ , independent of other customers. A service call request requires a trip to the customer, which takes a full day. Then, the number of service requests in a day has a binomial distribution with parameters  $n$  and  $p$ . The probability of exactly  $k$  service requests in a day is  $p^k(1-p)^{n-k} n!/(k!(n-k)!)$ . The mean of the distribution is  $np$ , the variance in the number of service requests is  $np(1-p)$ . For example, if  $n = 6$  and  $p = .1$ , then the probability of  $k = 0$  service requests is  $.9^6 = .531441$ . The probability of 1 request is  $.1*.9^5*6/5! = .354294$ . The probability of 2 requests is  $.1^2*.9^4 *15 = .098415$ . The binomial distribution with parameters  $n$  and  $p$ , converges to the Poisson distribution with mean  $np$ , as  $n$  gets large and  $p$  gets small. The binomial converges to the Normal distribution if  $p$  is close to .5 and  $n$  gets large.

- BOM (Bill of Material):** A listing for each product or sub-assembly of all the components or sub-assemblies that go into it and how many are required. See also MRP.
- Bonded storage:** secure storage for product for which taxes, such as excise tax, may become due when product leaves storage, depending upon its destination. The warehouse owner guarantees to tax/tariff collecting agencies that product will not be released without payment of any taxes due depending upon where the product is shipped.
- Box car:** A covered rail car, typically loaded and unloaded via forklift through doors on either side. This is typically forty to fifty feet long. In contrast, see flat, hopper and tank car.
- Braess's paradox:** The observation, supposedly made by Braess of traffic in Stuttgart, that for some traffic networks, if new link capacity is added to the network, the total traffic delay at user equilibrium may in fact get worse. The paradox arises because, when individuals optimize individually, they do/may not take into account the impact of their decisions on other parties. For example, when making the decision to take a car vs. a train, or a particular route, we tend to not take into account the additional delay that we may cause other commuters as a result of this decision. There is a strong form and a weak form. The strong form is that every traveler's travel time is no worse, with some of them experiencing reduced travel time. The weak form is only that total travel time is reduced. The use of "metering" lights at the on-ramps to some expressways is a way to avoid situations very similar to Braess's paradox. Traffic engineers have discovered that by restricting capacity on the on-ramp total delay is reduced. See also: Wardrop's Principle.
- Break bulk:** Disaggregate a big shipment from a single source (e.g., a manufacturer) into smaller quantities to be shipped as needed to multiple customers (e.g., retailers).
- BTU (British Thermal Unit):** A common measure of performance for energy producing or energy consuming products, defined as the energy in heat form needed to raise the temperature of one pound of water by one degree Fahrenheit. See calorie.
- Bucket Brigade:** A method for coordinating workers along a pick or production line. Workers remain in sequence as each moves forward with her job along the line. When the last worker completes her job, she takes over the job of her predecessor, who then takes over the job of her predecessor, and so on. Until the first worker introduces a new job to the line.
- Bull whip effect:** the observation in multi-echelon inventory systems that a small fluctuation in the demand per period at the retail end may result in a dramatic fluctuation in the amount demanded at the manufacturer, analogous to how a small flick of the wrist will cause the tip of a bull whip to move a great distance. The fluctuations in demand by the retailer on the supplier may be due to a number of reasons (e.g., order batching by the retailer if it uses a  $Q,r$  inventory model with a large  $Q$ , price changes by either the supplier or the retailer, or generally poor information sharing between the retailer and the supplier, so that the supplier is surprised by the large retailer demand when the retailer does a promotion).
- Bundle pricing:** A vendor does bundle pricing if the vendor sells two or more products as a bundle for a price lower than the sum of the individual product prices. The vendor can sometimes increase revenues thereby. As an example, suppose customer  $A$  is willing to pay \$800 for product  $X$  and \$400 for product  $Y$ . Customer  $B$  is willing to pay \$400 for product  $X$  and \$800 for product  $Y$ . If the vendor sets a single market price for each product individually, the most he can make is \$1600. If, however, the vendor sells the two products only as a bundle for \$1200, he can make \$2400.
- Burn rate:** term used, typically in consulting, for the rate at which cash is being spent, usually on personnel involved in implementation of some system.
- By-product:** a joint-product of small value relative to the other joint-products.
- Cabotage:** Carriage of goods or people between an origin and destination, both in the same state or country, by a carrier not from that state or country. Many states or countries have laws prohibiting such shipments by foreign carriers, except perhaps for "incidental" shipments which are the first step of shipping the good to a foreign state.

**CAD** (Computer Aided Design): A software system that at a minimum has an ability to give and manipulate a graphical display of the product being designed. It usually also has analysis capability (e.g., the ability to determine whether a rack of a given design can in fact support a specified weight). This analysis capability is frequently based on FEA.

**CAFÉ** (Corporate Average Fuel Economy): In the U.S., the NHTSA (<http://www.nhtsa.org>) requires that the average fuel economy of all passenger vehicles sold by a manufacturer in the U.S. must achieve a specified minimum average fuel economy measured in miles per gallon. For model year 2000, the minima were 20.7 mpg for light trucks (e.g., “sport utility vehicles”), and 27.5 for cars. The harmonic mean is used in computing CAFE. The penalty for not achieving it is \$5.50 for each tenth of a mpg by which a manufacturer falls short times the number vehicles sold.

**Call center:** A collection of agents staffing telephones. There are two major types of call centers, inbound and outbound. An inbound center handles calls arriving randomly from customers (e.g., ordering items from a catalog, reporting problems with your products, etc.) An outbound center originates calls to clients (e.g., soliciting new business, reporting problems with fulfilling their order, scheduling service visits, politely asking them to pay their account, etc.) See also: predictive dialing.

**Carmack amendment:** A U.S. Federal law that specifies liability limits of a carrier to a shipper for lost or damaged goods, as well as a time limit within which a shipper may file a claim. Liabilities limits may be based on such things as a maximum dollars per pound. State law is preempted by the Carmack amendment. See also Warsaw convention.

**Category management:** An allocation of management authority according to product type, typically in supermarket retailing. Example categories are: baked goods, produce, soft drinks, etc.

**Calorie:** energy in heat form needed to raise the temperature of one gram of water by one degree Celsius. 1000 calories = 3.968 BTU. A note of caution, the unit of energy referred to in the popular press as a calorie, is usually a kilo-calorie.

**Carousel:** A storage system in which product is brought to the picker, rather than the picker walking to the storage bin. The storage bins are typically mounted on motor driven chains. A vertical carousel may allow one to exploit higher storage for picking than one could with plain manual picking. In general, higher storage densities may be achieved, as well as higher pick rates per person.

**Carrier:** A firm that carries freight (e.g., a trucking firm). In contrast, see shipper.

**Case:** standard shipping unit to retailers (e.g., supermarket goods are typically shipped in units of a case. For example, 12 bottles of wine to a case). Multiple cases may in turn be bundled into a skid on a pallet for loading onto a truck with a forklift.

**c.d.f.** (Cumulative Distribution Function): The left tail probability of a distribution. For a given constant  $t$  and a random variable  $X$ , it is the probability that  $X \leq t$ .

**Cellular manufacturing:** A factory layout in which machines are grouped by product produced rather than by the more traditional grouping by function (e.g., all the cutting machines grouped together in one department, all the welding machines grouped in another department, and all the punching machines grouped together in a third department). In contrast, a manufacturing cell might have grouped together a single cutting machine, a single welding machine and a single punch, each appropriate for producing a specific product. The advantage of the cellular arrangement is that WIP and handling may be substantially reduced. In traditional manufacturing, the time in system for an item consists of: production time + wait for sibling parts of the batch to finish a step + wait to have batch transported to next step. In cellular manufacturing, the last two waits are eliminated. There can be several disadvantages to the cellular style: one may need moveable or flexible machines, so the appropriate machines can be quickly physically moved and grouped together as needed for the product. If substantial process specific skill is required to operate or maintain a machine, it may be easier to manage things if similar machines and/or laborers are physically close.

**Censored observation:** An observation is censored if it is only a bound on the actual value that one desires to observe. For example, sales data are usually censored observations of what we would really like to observe: demand data. This is because if a prospective customer sees that we are out-of-stock of the

item she would like to purchase (e.g., if we show our stock level on our website) then the customer typically will not bother to tell us what she wanted if the stock level is zero. Traditional catalog merchants on the other hand, force a customer to reveal what they would like to buy before the merchant reveals whether the product is in stock. In the same way, the catalog merchant gains more information about customers' willingness to substitute other products for out-of-stock products.

**Central limit theorem:** The result that a sum of random variables has the Normal distribution in the limit as the number of random variables in the sum gets large, as long as the random variables are independent and have bounded variance.

**Channel:** In marketing, the collection of firms from original manufacturer to final retailer who are involved with providing a specific good or service.

**Channel conflict:** A situation in which there is disagreement among members of a supply chain or channel on how it should be managed. A common example is when a manufacturer sells its product both through distributors as well as directly to the final retail customers. The distributors find themselves competing with their supplier for retail sales. At one time Compaq computer found itself in such a channel conflict situation when it tried to switch to a direct retail sale system from a distributor based system, so as to provide the fast response of its direct-sale-based competitor, Dell Computer.

**Chimney stacked pallet:** A skid/pallet stacked so that all items have at least one face on the outside. This may leave an empty vertical core so that the skid looks like a chimney. The customer (e.g., a retailer) of the skid may request this form of stacking, so that the pallet can be quickly checked for contents when it arrives at the customer. There are no items hidden on the inside that can be seen only after the skid has been broken down.

**CLM (Council of Logistics Management):** Not-for-profit organization for professionals interested in logistics management. See <http://www.clm1.org>

**Coase's law:** Due to Ron Coase, states that a firm will get large in a vertically integrated sense, or do more activities internally rather than outsourcing them to the extent that it is cheaper to do the activities in-house. Coase was originally impressed by the extreme vertical integration of firms such as Ford in the early 1900's. Coase paid particular attention to three kinds of transaction costs associated with outsourcing an activity: 1) Search costs, finding an acceptable supplier, 2) Contracting costs, the cost of managing the contract, and 3) Coordination cost (e.g., how to efficiently share the right information). Coase was a professor at the University of Chicago Law School and won a Nobel Prize for this work.

**COD (Cash on Delivery):** An arrangement whereby the buyer pays for the goods upon delivery, in contrast to FOB.

**Code sharing:** An airline practice in which two airlines (e.g., United and Lufthansa) sell tickets for the same flight (product code), usually an intercontinental flight. United will market the flight in the U.S. Lufthansa will market it in Europe.

**Coefficient of variation:** The standard deviation divided by the mean.

**COGS (Cost of Goods Sold):** An estimate of the cost of the goods sold in a period. This estimate may vary depending upon such things as whether LIFO rather than FIFO is used in accounting for inventory.

**Combinatorial auction:** An auction in which bidders may bid on combinations of objects as well as individual objects. For example, if a buyer needs 500 square meters of contiguous space and the seller is selling a number of properties, each with 250 square meters of space, the buyer would bid on a pair of adjacent properties.

**Compound Poisson Distribution:** A generalization of the Poisson distribution. It is representative of a demand process in which the number of orders in a specified period has a Poisson distribution, but additionally, the number of units requested in each order is also a random variable having some specified distribution. If  $\theta$  = mean number of orders received in a period and the number of units requested in each order has mean  $\mu$  and standard deviation  $\sigma$ , then the number of units requested per

period has mean  $\theta\mu$  and variance  $\theta(\mu^2 + \sigma^2)$ . If  $\theta_j$  is the mean number of orders of size  $j$  in a period, and  $P_n$  is the probability of total demand in units being equal to  $n$  in a period, then:

$$\begin{aligned}P_0 &= e^{-\theta}, \\P_1 &= \theta_1 P_0, \\P_2 &= [\theta_1 P_1 + 2\theta_2 P_0]/2, \\P_j &= [\theta_1 P_{j-1} + 2\theta_2 P_{j-2} + 3\theta_3 P_{j-3} + \dots + j\theta_j P_0]/j.\end{aligned}$$

**Condo:** A long distance trailer tractor that has a bunk for sleeping.

**Conjoint analysis:** A method for approximating the utility function of a typical customer for a class of products. Products in the class are assumed to be completely described by a set of factors or attributes such as length of warranty, wheelbase, fuel efficiency, etc. The total attractiveness or utility of a product is then assumed to be a weighted sum of these factor levels. The purpose of conjoint analysis is to find an appropriate set of weights. The usual method is to show each of a large number of consumers two or more different products and ask each consumer to rank the products by attractiveness. Linear programming can then be used to find a set of weights that are as consistent as possible with these rankings.

**Consolidate:** Combine many shipments to a common destination into a single shipment.

**Constant sum game:** See Zero sum game.

**Continuous move:** In trucking, the situation where a vehicle drops off a load at a site and then is able to pick up a load of something else at the same site to be hauled elsewhere, thus avoiding a deadhead.

**Control chart:** A simple graphical and statistical procedure for helping to discover controllable aspects of a production process, so as to help produce a less variable product. A typical application of a control chart is to measure the quality (e.g., weight, diameter, etc.) of individual products as they exit the production process. The units are grouped into batches of size 4 or 5. The mean and standard deviation are computed over say the first 20 batches. A chart is then constructed with a center line at the mean and upper and lower limits at plus and minus three standard deviations. The qualities of subsequent batches are then plotted on this graph. One looks for patterns in this graph, in particular trends. If such a pattern is discovered, it is probably an indication that there is something systematic going in the process (e.g., a tool is becoming loose, etc.) Thus, there is an opportunity and motivation to identify this cause, eliminate it, and thus produce a more predictable quality level. Variations and generalizations of this methodology are sometimes called statistical process control.

**CONWIP (Constant Work in Process):** a style of operating a production line so that the WIP remains constant. Initially a fixed number of units are released into the line. Subsequently, an additional unit is released to the line only when a unit finishes. This terminology and method was popularized by W.J. Hopp and M. L. Spearman. Note its similarity to a base stock policy and kanban.

**Cookie:** a file stored on your computer, typically stored in a subdirectory called cookies and/or called cookies.txt, in which information may be stored by websites that you visit. It is an efficient means by which a vendor with a website can do a simple form of CRM. Various tidbits of information about your interests can be stored in this file. For example, if you are greeted by name when you access a website such as Amazon.com, it is because your name is stored in a cookies file on your computer.

**Co-op advertising:** Advertising in which a retailer and a supplier share the cost of retail advertising. The reason for the sharing is that both the retailer and the supplier benefit from the advertising. Without the sharing, the retailer would advertise too little.

**Correlation:** A statistic, between  $-1$  and  $+1$  that measures the extent to which to random variables move together. For example, if  $X$  is larger than the mean implies that  $Y$  is larger than the mean, then  $X$  and  $Y$  will tend to be positively correlated, whereas if  $X$  is larger than the mean implies that  $Y$  is smaller than the mean, then  $X$  and  $Y$  will tend to be negatively correlated. Mathematically, the correlation is defined by  $\text{Covariance}(X, Y) / [\text{Variance}(X) * \text{Variance}(Y)]^{0.5}$ .

**Core of a game:** Given a set of cooperating players (e.g., a manufacturer, a wholesaler, and a retailer) an allocation of profits or costs is said to be in the core if no individual or subset of individuals can do better by themselves. For example, suppose customers  $A$ ,  $B$ , and  $C$  need to have material delivered.

They can save money if they hire a single trip to make the delivery to all three. How should the costs be shared? Example: the cost of delivering to any combination of the three is as follows:  $\{A\}$ : \$88,  $\{B\}$ : \$91,  $\{C\}$ : \$90,  $\{A,B\}$ : \$150,  $\{A,C\}$ : \$148,  $\{B,C\}$ : \$151,  $\{A,B,C\}$ : \$180. For example, making a single trip to just  $B$  and  $C$  costs \$148. Making one trip that serves all three costs \$180. If  $CA$ ,  $CB$ , and  $CC$  are the amounts the three players decide to assess each other, then the core of the game is defined by the constraints:

$CA \leq 88$ ;  $CB \leq 91$ ;  $CA \leq 90$ ; (Else the player is better off by himself);

$CA + CB \leq 150$ ;  $CA + CC \leq 148$ ;  $CB + CC \leq 151$ ;

(Else a given pair is better off to exclude the third from their coalition.

$CA + CB + CC = 180$ ; (Total cost must be allocated).

For example, even though the Shapley value suggests that  $B$  should pay 61.5,  $B$  might be able to successfully argue that everyone pay 60 each because (60, 60, 60) satisfies the above constraints and is thus in the core. The core may be empty. For example, suppose that the cost of covering all of  $\{A, B, C\}$  is \$231 rather than \$180. Thus, the average cost per customer of the total trip is \$77. Now, even though total costs are minimized by using a single trip, any pair,  $A$  and  $C$  in particular, may be tempted to drop out of the coalition and reduce their per-customer cost to \$74 from \$77. See also Nash equilibrium, Shapley value.

**Covariance:** A statistic that measures the extent to which two variables move together. Given a set of  $n$  paired observations:  $\{x_i, y_i\}$ , with respective means  $\bar{x}$  and  $\bar{y}$ , then the covariance of this sample is defined as:  $\sum_i (x_i - \bar{x})(y_i - \bar{y})/n$ . This is a biased estimate of the population covariance. To correct for this bias, change the denominator to  $n-1$  rather than  $n$ . Observe that the covariance of a variable with itself is its variance.

**CPFR** (Collaborative Planning, Forecasting, & Replenishment): A set of guidelines for how participants in a supply chain share information, mainly forecasts and plans for promotions. See also VMI, and <http://www.cpfr.org>.

**CPG** (Consumer Product Good): Essentially any product sold in a grocery or drug store.

**CPI** (Consumer Price Index): An index of prices paid by consumers. It is compiled by the U.S. Bureau of Labor statistics, <http://stats.bls.gov>. It is the price paid, including sales tax, for a “basket” of goods and services bought by a typical consumer. It is available at the national, regional, and metropolitan area level. One of the major purposes of the CPI is to measure inflation. See also: PPI.

**CPM** (Critical Path Method): Project management technique in which a project is represented as a set of activities, each having an activity time and a set of predecessors. A principal concern is the minimum length of time required to complete the project. Crucial output is a critical path, that is, a set of activities such that if any activity on a critical path is delayed, the project will be delayed. This is similar to PERT.

**CRM** (Customer Relationship Management): The process of managing the interaction with existing or potential customers, especially by telephone. Part of the process may involve having an extensive on-line database on individual preferences of each customer. This database may be accessed during the interaction with the customer. Also see RFM.

**Cross docking:** A system for operating a DC in which product from inbound vehicles moves almost immediately to outbound vehicles without being put into storage. The supplier of the inbound product may be a completely different firm from the receiver of the outbound product. The major purpose of a cross docking DC may be to “break bulk” at some level (e.g., down to the skid level and “consolidate”). See also DC.

**Croston’s forecasting method:** A method for forecasting lumpy demand (i.e., when a significant number of the periods have zero demand). Standard forecasting methods, such as simple exponential smoothing, perform erratically on lumpy demand. When no demand occurs, no update is performed. When a positive demand occurs, three exponential smoothing updates are performed of the three estimates of: a)  $Tbar$  = the time between positive demands, b)  $Dbar$  = the amount of demand when it is positive, and c) the absolute deviation in positive demand. The forecast of expected demand per period

is  $Dbar/Tbar$ . See Croston, J.(1972), "Forecasting and Stock Control for Intermittent Demands", *Operational Research Quarterly*, vol. 23, no. 3, pp. 289-303.

**Cube:** typically refers to the volume of a commodity (e.g., as in cubic meters).

**cwt.:** hundred weight, one hundred pounds. For many products (e.g., raw milk) the standard unit of measure is the cwt.

**Data Matrix code:** A two-dimensional, laser scanable code used for supply chain purposes by the pharmaceutical and consumer electronics industries. The code is made up of very small black and white squares. Other two dimensional codes include PDF 417 and MaxiCode. For more details, see [www.aimglobal.org](http://www.aimglobal.org).

**DC (Distribution Center):** A facility that accepts inbound shipments, breaks them up and recombines them differently into outbound shipments. For example, it may accept a shipment of baby food from Gerber and a shipment of diapers from Kimberly-Clark and recombine them into one shipment of baby food plus diapers for a Jewel supermarket and another shipment of baby food plus diapers to a Safeway supermarket. A DC may also serve as a warehouse (i.e., store product for a nontrivial period until it is needed by retailers or customers). It may contain product handling equipment such as a sortation system and storage racks. A clear height of 24 feet for storage is typical.

**Deadhead:** A positioning trip, in which the vehicle is empty (e.g., an empty return trip). A backhaul is preferred to a deadhead.

**Delphi method:** Forecasting method developed at Rand Corporation in 1969, mainly for technology forecasting. A panel of experts is identified and then a forecast is developed via a series of two to four rounds. In each round each expert is asked to provide forecasts regarding some specified product or technology. The results are then summarized and distributed back to the experts in preparation of the next round. A notable feature is the anonymity. The participants are not identified. Relative to a focus group the apparent advantages are: a) there is no need to have the experts together simultaneously, b) the anonymity helps alleviate undesirable "bandwagon" effects and the ill effects of an opinionated ignoramus with a strong personality.

**Demurrage:** Payment by a user of shipping to the carrier for not loading or unloading a vehicle or returning a container in reasonable time, forcing the carrier to wait. For rail cars, a shipper or receiver typically has 48 hours to load or unload a car.

**Dense storage:** See movable aisle storage.

**DFR (Decreasing Failure Rate):** A failure rate curve such that the probability of failing in the next instant, given that the machine has not yet failed, is decreasing with time.

Thus, preventive replacement is not a good thing to do. Equipment that has a DFR is like good red wine. It improves with age. Some semi-conductor equipment has DFR reliability. See also DFR, MTBF.

**DIME (Dual Independent Map Encoding):** A digital mapping system from the U.S. Census Bureau, now superseded by TIGER data.

**DFM (Design for Manufacturing):** The most important consideration in designing a product is to make it satisfy the customer's needs. There may, however, be alternate designs that all satisfy the customer needs, but some of which may be substantially easier to manufacture. Thus, in DFM, the product designer takes into account not only customer needs, but also the problems faced by the manufacturing engineer who must design a production process for producing the product in the volume demanded. DFM is just one of DFX design philosophies, where X might be manufacturing, serviceability, reliability, recyclability, etc. A more serviceable design, for example, might make it easier to remove and replace a failed component, or might share components with a related product, so that spare parts inventories are easier to manage.

**DISA (Data Interchange Standards Association):** An association devoted to the maintenance and dissemination of standards for e-commerce documents, such as the X12 and XML. See:

<http://www.disa.org>.

**Discriminant analysis:** A methodology for computing a scoring function that can be used for classifying objects into two or more categories. For example: should a prospective customer be given credit or not; should a current customer receive or not a certain kind of advertising brochure; should an x-ray be classified as indicative of cancer or not. It is somewhat analogous to regression but with a yes/no or categorical dependent variable. See also logit analysis, probit analysis, and neural nets. Ref: Gochet, Stam, Srinivasan, and Chen (1997), *Operations Research*, vol. 45, no. 2.

**Discriminatory pricing:** charging different prices to different customers for the same product. The segmentation might be based on customer id (e.g., educational vs. commercial), time of purchase, quantity, location, by metering of use, etc. See: revenue management and value based pricing.

**Dock:** door in a plant or warehouse for loading and unloading trucks. Typical additional features are: a) some kind of floor leveler ramp to compensate for difference in height of the truck floor and the warehouse floor, so that forklifts can drive onto the truck. b) Curtains that surround the truck door to provide protection from the weather for personnel loading or unloading the truck. c) A dock door that is used mainly for unloading is sometimes called a strip door.

**DOT** (Department Of Transportation in the U.S.): The main federal agency concerned with transportation in the U.S. Sub agencies under the DOT include: Bureau of Transportation Statistics, US Coast Guard, FAA, Federal Highway Administration, NHTSA, and STB. See <http://www.dot.gov>.

**Double marginalization:** The act of two decision makers (e.g., a supplier and a retailer) each independently optimizing their own objective function (e.g., by choosing a volume, so that marginal cost = marginal revenue), but with the unhappy result that their total profits are not as great as they could be if they coordinated their decisions. More specifically, the supplier, in order to make a profit, will charge the retailer a little more than the supplier's cost. Thus, the retailer will charge the customer slightly more than he would if the retailer had to pay the supplier only the supplier's cost without a markup. Thus, the retail price will be higher than it would be if the supplier and retailer coordinated their decisions, and demand will tend to be lower.

**Drayage:** local trucking (e.g., at the beginning of a long trip).

**Drop ship:** A shipment in which the order taker (e.g., a catalog or internet merchant) asks a manufacturer to ship product directly to the order taker's customer.

**DRP** (Distribution Requirements Planning): A form of scheduling shipments and production analogous to MRP. Given the requirements over time of various customers of a supplier, these needs are aggregated into a single shipping, and perhaps production plan for the supplier.

**Dual price:** In linear programming terminology, the marginal value of one more unit of a scarce resource. Sometimes also called a shadow price.

**Dumping:** the selling of a product from state  $X$  in a state  $Y$  at a price that is lower than some parties in state  $Y$  would like. The typical argument is that the product is being sold at a price lower than its average cost, although not necessarily below its marginal cost.

**Dunnage:** Filler or packing material placed between cargo on a vehicle to prevent the cargo from shifting.

**Dutch auction:** In the Dutch flower market, this is an open, price descending auction. As the price descends on a large dial in the front of bidding audience, the first bidder to indicate a willingness to pay by pressing a button, wins. It gives approximately the same result as a sealed bid auction in which the highest bid wins and pays the amount bid. It may lead to inefficient outcomes in that if given the opportunity after the auction, unsuccessful bidders might be willing to pay more than the winning price if allowed to change their bid. It has the advantage of being fast. For contrast, see: Vickrey auction.

**Duty:** a tariff or tax on imports. It is imposed typically to either protect domestic industry or as a punishment on a political enemy.

**Duty avoidance:** the right of a firm to avoid paying a portion of the duty on an imported product because the firm has previously exported a component equivalent to one contained in the imported product.

**Duty drawback:** a refund to a firm when it exports a product, in the amount equal to the duty the firm previously paid when importing components used in the exported product. It achieves, by accounting, the same effect as a duty free zone.

**Duty free zone:** a zone in which a firm does not have to pay duty on imports, as long as the products imported, after some processing or handling, are exported.

***e*:** The mathematical constant 2.71828182846 useful in computing continuous compounding of interest.  $e = \text{limit as } n \text{ goes to infinity of } (1 + 1/n)^n$ . For example, if continuous compounding is used at interest rate  $r$  per year, then after  $n$  years, one dollar will have grown to  $e^{rn}$ .

**eaches:** In warehouse picking, a single unit to be picked, as opposed to a case.

**EBITDA** (Earnings Before Interest, Taxes, Depreciation, and Amortization): A measure of the profit due to operations, excluding cost items related to how financing, tax deferral, and other non-operations activities are performed.

**Echelon inventory:** assuming product is measured in same units throughout the supply chain, the echelon inventory at a given level in a multi-echelon system is the inventory at that level plus all downstream (i.e., towards the consumer, levels). For contrast, see: pipeline inventory.

**ECR** (Efficient Consumer Response) Terminology used in the grocery industry for JIT, short lead time distribution.

**EDI** (Electronic Data Interchange): A method of electronic interchange for business-to-business transactions developed before the internet. It specifies electronic format standards for about 150 different data fields for common business documents such as PO's, invoices, etc. The standard is sometimes called EDIFACT or X12. Information about a wide variety of international standards is available at <http://www.nssn.org>. See also X12.

**EDLP** (Every Day Low Prices): The seller (e.g., a grocer) maintains a constant low price, as opposed to usually high prices with an occasional short promotion period of very low price. See also: forward buying.

**Efficient frontier:** Given a multi-dimensional measure of goodness (e.g., product price, delivery time, and product quality), a point is said to be on the efficient frontier if there is no other point, which is at least as good on every measure and strictly better on at least one measure of goodness. See also, tradeoff curve.

**Elasticity of demand:** (% change in quantity demanded)/(% change in price). If the elasticity = 1, then a small change in price will not change the seller's sales revenue.

**EOQ** (Economic Order Quantity): An order size that minimizes the sum of fixed cost of ordering plus inventory costs. If  $K$  = fixed cost of placing an order,  $h$  = holding cost, and  $D$  = demand rate, then the order quantity is given by  $Q = (2 * K * D / h)^{.5}$ .

**EPC** (Electronic Product Code): A proposed 96 bit code to be used to identify individual product items (not just SKU's) in the same manner as a serial number. The code is stored in RFID tags on the product. This would allow a firm to easily track items through the supply chain. See <http://www.autoidcenter.org>, UPC.

**Erlang B formula:** See Erlang Loss.

**Erlang C formula:** A formula for the expected fraction of calls that must wait, in a system with  $S$  lines or servers, where demand has a Poisson distribution with rate  $D$ , call processing times have an exponential distribution with mean  $L$ , and calls that find all lines busy will wait. The formula was originally developed by A. K. Erlang for the Copenhagen telephone system. If we define the arriving load as  $r = D * L$ , then in the LINGO modeling language, the expected fraction of calls that find all  $S$  lines busy (and thus wait) is given by @PEB (  $r$ ,  $S$  ). If we denote this probability by  $C(r,S)$ , then it can also be computed from the Erlang Loss formula,  $B(r,S)$ , by the relation:  $C(r,S) = r * B(r,S) / (S - r + r * B(r,S))$ ;

**Erlang Loss Formula:** A formula for the expected fraction of sales lost, when a base stock policy is followed, demand has a Poisson distribution, and any demand that finds the system out of stock is lost. The formula was originally developed by A. K. Erlang in the telephone industry to predict the expected fraction of calls lost, given a fixed number of lines. If  $D$  is the demand rate,  $L$  is the expected lead time (or call processing time),  $S$  is the stock level (or number of phone lines) and  $r = D*L$ , then the expected fraction demand lost,  $B(r, S)$ , can be calculated recursively as follows:  $B(r,0) = 1$ ;  $B(r,S) = r*B(r,S-1)/(S + r*B(r,S-1))$ . It is available in the LINGO modeling language as @PEL( $r, S$ ). Also known as the Erlang B formula.

**ERP** (Enterprise Resource Planning, see also MRP and DRP): Comprehensive software system for the firm that, at least in theory, has coordinated modules to perform all the standard business data processing functions such as: General ledger (GL), Accounts receivable (AR), Accounts payable (AP), Asset management (e.g., depreciation), Human resources/payroll (HR), Forecasting, Purchasing, Inventory, Materials Requirements Planning (MRP), Production Planning, Warehouse Management (WMS), Sales, Order management, and Distribution .

**Experience curve:** term used by Boston Consulting Group for learning curve.

**Exponential distribution:** If  $D$  is the arrival rate of retail demands, and the number of demands per unit time has the Poisson distribution. Then, the time between successive demands has the exponential distribution. Specifically, if  $t$  is the time between successive demands, then the p.d.f. is  $D*e^{-Dt}$ , and the c.d.f. is  $1 - e^{-Dt}$ . An interesting feature of the exponential distribution is the memoryless property (i.e., if the time between demands is exponential), then at any instant, the distribution of the time to the next event has the exponential distribution, regardless of the time since the previous event.

**Exponential smoothing:** a weighted moving average forecasting method in which the weight applied to old data decreases exponentially with age. In its simplest form, if  $D(t)$  is the demand observed in period  $t$ ,  $S(t)$  is the forecast computed after observing  $D(t)$  and  $alpha$  is the smoothing constant (e.g., 0.2, then  $S(t) = alpha*D(t) + (1-alpha)*S(t-1)$  ). It is a special case of the ARIMA class of forecasting models. There are extensions to include trend, seasonality, and estimation of demand variability. See also, Croston's method.

**Extranet:** a communication network setup among a set of firms that do business together. It is typically based upon IP, but restricted in some way to only a limited set of firms.

**Failure rate curve:** A curve that plots a machine's probability of failure in the next small interval of time, given that the machine has not yet failed. If the time to failure has an exponential distribution, then the failure rate curve is constant. See also: MTBF, IFR, DFR, and bathtub curve.

**FASB** (Financial Accounting Standards Board): An independent board for setting standards for reporting financial information by firms. These standards specify such things as what and when items can be claimed as income or expense. Tel: 203-847-0700. These standards are officially recognized by the SEC and the AICPA.

**FEA** (Finite Element Analysis): A method for analyzing or modeling a wide variety of physical systems, such as structures, weather, etc. A key feature is that the system is viewed as a large collection of discrete points. The state (e.g., temperature, pressure, tension) of each point is related to the state of its neighbor points by a set of equations appropriate for the application. A computer program (one of the earliest was called NASTRAN) is then used to solve this large set of equations. FEA is usually a crucial component of CAD.

**FEM** (Finite Element Method/Modeling): See FEA.

**FICA** (Federal Insurance Contributions Act): Law describing Social Security tax/payouts.

**FIFO** (First In First OUT): Inventory policy in which product is used in the order in which received. See also LIFO. In times of rising prices, a firm can manipulate its apparent COGS by switching between LIFO and FIFO.

**Fill rate:** the fraction of demand that is satisfied immediately from inventory. See also line item fill rate, order fill rate, and linear loss function.

**Flat car:** A rail car without top or sides. Typically used for hauling heavy machinery or piggy back trailers. In contrast, see box, hopper, or tank car.

**Flow rack:** A warehouse storage rack inclined to the front with a lip at the front, so that when a picker removes a box from the front, boxes from the rear slide forward.

**Flow through warehouse:** Cross docking with the additional feature that the product is modified in some way (e.g., a brand name label is added).

**FMS (Flexible Manufacturing System):** A production system with machines that can be quickly changed to produce a different product. The machines are typically software controlled and can change tools automatically (e.g., replace a 10 mm drill bit by a 12 mm drill bit). See also cellular manufacturing.

**Forklift:** a powered (e.g., by battery or by a low exhaust emission propane fueled engine) vehicle, typically with a fork-like pair of tines in front for lifting product, typically on a pallet, and moving it, (e.g., on or off a truck), out of or into rack storage.

**Forward buying:** The process of buying several periods worth of supply when a supplier does a “price promotion”, that is, temporarily lowers the price. If all buyers forward buy, then the supplier might as well use EDLP. The seller would have the same total revenue but in a steadier stream and the buyers would have lower average inventory.

**FOB (Free On Board/Freight On Board/From Our Base):** An FOB price is the price for a product picked up at the seller’s site. The buyer must supply, or at least pay for, transportation. See in contrast, COD.

**FTL (Full Truck Load):** An FTL shipment is one in which an empty vehicle picks up material at a supplier and then drops off the entire contents at a single destination. The carrier typically charges an amount based on the distance traveled rather than on the weight or volume of the contents. The cost per unit shipped is usually less than that under LTL shipping.

**Franchise:** the right to sell a product at a given location. For example, the right might be given by an automobile manufacturer to an automobile dealer, or by a fast food brand owner to a restaurant owner.

**Free rider problem:** When two or more players (people in a firm, firms in a supply chain) share revenue from an enterprise that depends upon both of their inputs, the free rider problem arises if additional effort by one player results in increased revenue that is shared by all players. Thus, a player that is selfish and does not expend any additional effort may nevertheless get a “free ride” (i.e., increased reward), because of the increased effort of other players in the enterprise. The obvious way of avoiding the problem is to set up incentives, so that the individual player’s increased reward is equal to the cost of his increased effort. This may imply that one must have a monitoring system to measure the effort of each player.

**Gambler’s Ruin:** A characterization of the fact that even if the odds are in our favor, we may still go broke when facing a bigger competitor in a situation where chance plays a role. Specifically, if at each encounter, we either win a dollar from our competitor with probability  $p$  or lose a dollar with probability  $q = 1-p$ . Then, our starting wealth is  $\$w$  and our competitor’s wealth is  $\$u$  and the probability that our competitor will go broke before we go broke, is:  $[1-(q/p)^w]/[1-(q/p)^{w+u}]$ . Verify that even if  $p > 0.5$ , if  $u$  is large relative to  $w$ , the probability is low that our competitor will go broke first. In the special case when  $p = 0.5$ , the probability that our competitor goes broke first simplifies to  $w/(w+u)$ . See also Lanchester equations.

**GATT (General Agreement on Trade and Tariffs)**

**GHz (Giga Hertz):** Billion cycles per second.

**GIS (Geographical Information System):** A system based around an accurate, detailed database of all streets, highways, addresses, and other physical features in a region, usually complemented with a graphical display capability. Also see TIGER.

**GL (General Ledger):** An aggregate summary of account balances of the firm (e.g., it contains summaries of AR, AP, Payroll, etc.).

**GPS** (Global Positioning System): A system for accurate determination of a vehicle's position, based on accurately measuring the distance to four or more satellites. The satellites transmit precisely synchronized signals based on a very accurate clock in each satellite. The receiver estimates distance from each satellite and, thus, its location by observing the phase differences of the signals from the satellites.

**Gray market:** The reselling of a product in a "market" other than which it was bought and in which the manufacturer intended. For example, some software vendors have charged less for a product in the U.S. market than in the European market. Thus, some arbitragers have been tempted to buy the product in the U.S. and resell it in Europe, thus possibly reducing the profits of the manufacturer. See revenue management.

**Great Circle Distance:** Shortest distance between two points over the surface of the earth. If  $LAT_i$  is the latitude of point  $i$  in radians, and  $LONG_i$  is the longitude of point  $i$  in radians, then the great circle distance in miles between cities  $i$  and  $j$  is  $3959 * \text{acos}(\sin(LAT_i) * \sin(LAT_j) + \cos(LAT_i) * \cos(LAT_j) * \cos(\text{ABS}(LONG_i - LONG_j)))$ . Note that 3959 is the approximate radius of the earth in miles. Degrees can be converted to radians by multiplying by  $3.1415926/180$ . ACOS is the arc cosine.

**Group technology:** A methodology, largely of European origin, for classifying parts to be manufactured into classes or groups, so that parts that are close together in the classification tend to be manufacturable by the same methods.

**GTIN** (Global trade item number): A code, similar to UPC, for identifying products or SKU's.

**Hazmat:** hazardous material. Examples include flammable, explosive, poisonous, radioactive, and corrosive materials. In the U.S., the Office of Hazardous Materials Operations in the DOT enforces regulations regarding the transportation of hazmat.

**Hectare:** A unit of land area, originally French = 2.47 acres = 11954.8 square yards.

**HEPA:** High Efficiency Particulate Air filter. By DOE rules, a dry, disposable filter that removes at least 99.97% of particles that are .3 micrometers in diameter. May be required for production processes that generate hazardous particulate pollution.

**Hopper car:** A railcar for carrying loose material such as grain. It has either an open top or hatches, so that it can be loaded from the top. It typically has a sloped bottom, so that the car can be emptied over a pit by opening slits in the bottom of the car. In contrast, see box car or flat car.

**HR** (Human Resources): that part of the business concerned with hiring, payroll, health, and pension plan management, etc.

**HTML** (Hyper Text Markup Language): Standard format for describing Web pages. See <http://www.w3.org/HTML/>. See also XML.

**Hub:** A central facility through which all shipments pass in a transportation system, or all communications are routed in a communications network. Given  $n$  sites with each site requiring shipments to up to  $n-1$  other sites, there are three basic methods of handling these requirements: 1) hub system, 2) direct ship or link, 3) traveling salesperson (TSP)/ring network. If capacity is lumpy (e.g., it only comes in 20 ton) truck increments, and the amount to be shipped from any origin to any destination is typically less than half of one of these lumps, then a hub system may be the cheapest method. Thus, a vehicle will pick up all outgoing material from given site, deliver it to the hub where it is sorted onto outgoing vehicles, and then for a given site, a single vehicle will deliver all incoming demand. If the amount to be shipped from any origin to another destination is large relative to a capacity lump, then direct ship may be the cheapest method. If the amount to be shipped from any origin to any destination is substantially less than the capacity lump size, then the TSP structure may be cheapest. That is, a single vehicle makes a tour of all sites, picking up and dropping off product as appropriate. For a telecommunication network, this corresponds to a so-called ring network. See also DC.

**HVAC** (Heating, Ventilating, Air Conditioning)

**IATA** (International Air Transport Association): An association/cartel of most of the world's passenger airlines for coordinating such things as fares on international flights. See <http://www.iata.org>. Icelandair was an early nonmember.

**ICC** (Interstate Commerce Commission): A U.S. federal transportation regulatory agency that was legislated out of existence as part of transportation deregulation. See STB.

**IFR** (Increasing Failure Rate): A failure rate curve such that the probability of failing in the next instant, given that the machine has not yet failed, is increasing with time. Thus, preventive maintenance tends to be a good thing to do. Incandescent light bulbs, for example, tend to be IFR. Once they have accumulated 1000 hours, the probability of failure increases. See also DFR, MTBF.

**i.i.d.** (Independent, Identically, Distributed): random variables, which have the same distribution and are independent in the sense that knowledge of one variable's value provides no information about the value of another.

**Inbound**: A shipment into a DC. Tends to be on larger vehicles.

**Incentive compatible**: A feature of a business agreement such that when the individual partner maximizes his own profits, he will also maximize the total profits of all partners to the agreement. Such an agreement typically involves some form of revenue sharing. See also: co-op advertising, transfer price.

**INFORMS** (INstitute For Operations Research and Management Sciences) <http://www.informs.org>.

**IP** (Integer programming): a generalization of linear programming that allows some variables to be restricted to integer values. It is very useful for planning models with go/no-go decision variables.

**IP** (internet protocol): a widely used standard format for moving data over a network based in part upon breaking a message into packets of standard size, with the first few bytes providing the destination address.

**Item fill rate**: fraction of items ordered that were in fact shipped. See order fill rate and line item fill rate.

**Inter-modal**: see multi-modal.

**Internet**: a large set of computers connected by a physical network that uses the IP method of communication.

**Intranet**: a communication network within in a firm, typically based upon IP, but physically restricted to only users within the firm.

**Inventory turns**: a variation of the Little Flow equation. It states: (turns per period) = (sales or transaction per period)/(inventory level) = 1/(average time in system).

**IRI** (Information Resources, Inc.): A Chicago based supplier of industry sales data for consumer products (e.g., supermarkets). These data are obtained from sources such as cash register scanners. Another supplier of such data is A.C. Nielsen.

**ISBN** (International Standard Book Number): A ten digit product code used for book products. The first digit represents the country, the next several digits the publisher, the next several digits the product, and the final digit is a check digit =  $(1*d_1 + 2*d_2 + \dots + 9*d_9) \bmod 11$ . A check digit of 10 is represented by *X*. The check digit will catch any single digit error or any single transposition. See also UPC.

**ISO** (International Standards Organization): An international organization to coordinate the setting of standards to facilitate international commerce. See <http://www.iso.ch/welcome.html>.

**ISO 9000**: a set of standards, originated in Europe, for business processes. A firm that is ISO 9000 certified has its major business processes well documented and is supposedly a more reliable business partner.

**Jake brake**: A feature of some truck engines, so that the engine, rather than the conventional brakes, can be used to slow down the truck. This saves wear on the brakes. The engine tends to be very noisy when used as a Jake brake. Thus, some communities prohibit the use of Jake brakes.

**JIT** (Just In Time): A form of inventory management in which product is transported in small batches, so that very little inventory is carried because components are delivered just as they are needed. See base stock.

**JIT-II**: A style of business coordination, initiated at Bose, whereby a firm's suppliers and carriers have a full time representative at the firm to coordinate the supply process.

**joint-product**: one of two or more products (e.g., skim milk and cream) produced by a single production process. See also by-product.

**Kaizen**: a Japanese business philosophy meaning to seek continuous improvement.

**kanban**: WIP inventory control system developed at Toyota. A kanban (literally "action plate" in Japanese) is analogous to a recirculating internal PO. That is, when a unit is taken from inventory, a request is automatically generated to the supplier to provide another unit. It is a "pull" system, roughly equivalent to a base stock inventory system. The number of kanbans inserted into the system is essentially equivalent to the reorder point  $r$ .

**kilogram**: 1000 grams. 2.2046 pounds. See SI units.

**kit**: a collection of components placed together, perhaps in a container, that tend to be used together. For example, one may have a standard repair kit for a repairman that contains the components that strike the best compromise of being most likely to be needed, cheap, complementary, and small.

**knot**: 6,076 feet/hour.

**Lanchester equations**: a pair of differential equations that describe the losses incurred by two competitors or combat forces as a function of their sizes. In discrete time, if the size of the two forces in period  $t$  are  $A_t$  and  $D_t$  and  $K$ ,  $r$ , and  $s$  are parameters, then:  $A_{t+1} = A_t - KA_t^r D_t^s$ , and  $D_{t+1} = D_t - KD_t^r A_t^s$ . Typical cases are a)  $r = s = 1$ , and b)  $r = 0, s = 1$ . Parameter  $K$  corresponds approximately to a probability of success. Either case illustrates the importance of concentrating one's efforts. The essence of these equations was given by F.W. Lanchester in 1916, and by M. Osipov in 1915.

**Lane**: shipping along a specific origin-destination pair. Typically the origin-destinations are city to city, but they might also be state to state, city to state, etc.

**LASH** (Lighter Aboard SHip): A multi-modal form of shipping in which small barges are carried on ocean going ships. A standard size of such barges is 44 feet by 26 feet with a capacity of 385 metric tons. A LASH ship may carry about 80 LASH barges.

**League**: An ancient measure of distance equal to approximately three miles.

**Learning curve**: A model of the time or cost to perform some task that quantifies the observation that time to perform the task decreases the more times the task is performed. This was first observed by T. P. Wright in the 1930's with regard to the number of labor hours required to assemble aircraft. A typical observation was that each time the cumulative production doubled, the time per unit decreased to, say, 80% of its previous value. This leads to a mathematical form:  $T(v) = T(1) * v^{-b}$ , where  $v$  = cumulative units produced, and  $T(v)$  = time or cost to produce unit number  $v$ . An 80% learning curve corresponds to  $b = 0.322$ .

**Letter of Credit**: A document from a reputable bank to party A, saying that party B has a specified amount of money on deposit for the purpose of buying something from A.

**LIFO** (Last In First Out): Inventory policy in which the last item added to inventory is the first one used. It is of interest for tax purposes in that in a time of rising raw material prices, taxable profits are postponed. See also FIFO.

**LIFR** (Line Item Fill Rate): The fraction of line items that are filled. For example, if a line item in an order requests ten units, then the line item is defined as filled only if all ten units are shipped. If all line items request just one unit, then the line item fill rate is the same as the item fill rate. See also order fill rate and item fill rate.

**Linear programming:** a mathematical procedure for maximizing a linear function subject to linear inequality constraints. George Dantzig gave a general statement of the problem and invented the Simplex method for solving linear programs.

**Line item:** One line in a purchase order requesting a certain amount of one SKU.

**Linear loss function:** = expected value of  $\text{Max}\{0, X - S\}$ , where  $X$  is a random variable (e.g., demand) and  $S$  is a threshold (e.g., the stock level). Therefore, in an inventory setting, it is the expected amount of unsatisfied demand. In the LINGO modeling language, the linear loss function for the standard Normal distribution is given by the function  $\text{@PSL}(z)$ . For a Poisson distribution with mean  $D$ , it is given by  $\text{@PPL}(D, S)$ . If  $F(z)$  and  $f(z)$  are the c.d.f and p.d.f. of the standard Normal, then  $\text{@PSL}(z) = z * F(z) + f(z) - z$ .

**Little's Flow Equation:** states that (average inventory level) = (average throughput rate) \* (average time in system).

**Load planning:** The process of deciding which items get loaded where in a truck, airplane, container, or ship. For a LTL truck, you want to load items in the reverse order of which they will be removed (assuming unloading from the rear). For ships and airplanes, you want the center of gravity of the load to be close to the center of lift or support. You want the heaviest item to be closest to the center of support, so as to reduce the stress. For a truck, you want the load evenly distributed over the axles, so as to not violate axle weight limits.

**Logit model:** A statistical technique frequently used in deciding whether to grant or deny credit to a prospective customer. Given various features of customer  $i$ ,  $x_{i1}, x_{i2}, \dots, x_{in}$ , the logit model determines weights  $w_0, w_1, \dots, w_n$ , to compute a score  $s(i) = w_0 + w_1 * x_{i1} + \dots + w_n * x_{in}$ . Prospects with a high score are granted credit; prospects with a low score are denied credit. Probability of being bad (0) is based on the logistics distribution and is given by:  $\text{Prob}\{i \text{ is bad} \mid s(i)\} = 1 / (1 + e^{-s(i)})$ . See also Probit model.

**Lot-splitting:** A manufacturing convention of splitting a final order size into smaller lots at some point in the production process. For example, suppose a customer orders 100 angle rings and producing angle rings requires two steps (rolling and welding). We lot split if after rolling the first ten rings, we ship this sub-lot of ten on ahead to begin the welding operation. The advantage is that for our little example, the lot splitting may allow the order to get through the factory in almost half the time. The disadvantage is that administrative costs may increase if we do not have a good way of keeping track of the status of all the sublots of a final lot. JIT is based in large part on lot-splitting.

**LP:** see linear programming.

**LTL (Less Than Truckload):** A shipment that shares space on the vehicle with shipments destined for other recipients. A vehicle that makes multiple stops, dropping off or picking up only a portion of its load at each stop.

**MAD (Minimum Absolute Deviation):** A measure of statistical error defined as the average absolute deviation between the forecast and the actual, or perhaps alternatively between the mean and the actual. Contrast this with standard deviation, which measures the average squared difference. If our costs (e.g., shortage or inventory) are simply proportional to our overage or underage, then MAD may be a more useful measure of error. One of the early motivations for using the MAD in forecasting systems was that the MAD takes about half as much work to compute as the standard deviations. For random variables with a Normal distribution, the standard deviation is approximately equal to  $1.25 * \text{MAD}$ .

**Manifest:** A list of the contents of a shipment (e.g., passengers on a flight) contents of a shipping container, etc.

**MAPE (Mean Absolute Percentage Error):** The mean absolute forecast error divided by the average demand times 100. It is always non-negative and may be greater than 100.

**Maquiladora:** Mexican manufacturing plant on the U.S. border.

**MaxiCode:** A two-dimensional bar code used by UPS and other firms in the transportation industry. The code has a distinctive bullseye in the center. Other popular 2-D codes are PDF 417 and Data Matrix. For more details, see [www.aimglobal.org](http://www.aimglobal.org).

**Metcalfe's Law:** The observation that the usefulness of some products increases with the square of the number of users of the product, because of a networking effect. Such a product is useful mainly because other people also have the product. Examples are telephones, the internet, and data format standards. Named after Robert N. Metcalfe, an early designer of the internet, Ethernet, and founder of 3Com Corporation. His most original work was done at Xerox PARC.

**METRIC (Multi-Echelon Technique for Recoverable Item Control):** A model for determining stock levels at a single DC serving multiple outlets. Both the DC and the outlets follow a base stock policy. It was developed initially for setting spare parts inventory levels for the U.S. military and NATO. See Sherbrooke, C.C.(1992), *Optimal Inventory Modeling of Systems: Multi-Echelon Techniques*, John Wiley & Sons.

**Metric ton:** 1000 kilograms, 2,204.6 pounds.

**MHz (Mega Hertz):** Million cycles per second.

**Milk run:** A trip with either several pickups or several delivery stops. See also LTL.

**Milling-in-transit:** A form of quantity discount sometimes offered by railroads. If a food processor ships wheat from Kansas to St. Louis, where the wheat is converted into flour, and then ships the flour to New York on the same railroad, the railroad might give a reduced rate as if it were a single shipment from Kansas to New York.

**Mixing center:** A DC whose main purpose is to recombine inbound shipments into outbound shipments containing the proper mix of products.

**Monte Carlo:** The use of random numbers to analyze the behavior of a probabilistic system. The term was coined by Stan Ulam, while working on the Manhattan Project, in honor of the Mediterranean city famous for its games of chance.

**Moral hazard:** Suppose firm or individual  $X$  must make a decision that in part determines how much risk to incur. Now, suppose  $X$  and firm or individual  $Y$  reach an agreement whereby  $Y$  bears some of the risk associated with  $X$ 's decision. An example of such an agreement is if manufacturer  $X$  buys fire insurance for its manufacturing plant from insurance company  $Y$ . The fact that as a result of the agreement,  $X$  may not be as diligent in preventing fire as it would be if  $X$  had to bear all the risk, is an example of moral hazard. Another example is if a manager receives substantial reward if a new product is successful in a new market, but is not penalized proportionately for the cost of failure if the product fails in a market, then the manager is not as motivated to do a good analysis beforehand of which markets are likely to be successful.

**Moveable aisle storage:** A storage system in which the storage modules are on tracks, so that adjacent modules, banks, or racks can be moved together with no gap, eliminating the aisle. A system with  $n$  banks could, at maximum density, be set up to use only one aisle, rather than  $n-1$ . Thus, if aisles are as wide as banks, one could get up to  $n-2$  additional banks by switching to a moveable aisle system, thereby almost doubling the storage density. The disadvantages are the additional cost and the fact that one cannot pick simultaneously from all banks. Thus, it tends to be useful mainly for low demand rate items, such as in libraries.

**MRO (Maintenance, Repairs, & Operations)** Usually used as an adjective, as in MRO inventory, to indicate materials that need to be purchased and stocked to support maintenance and repairs. This is in contrast to material that is purchased to be assembled into a product and shipped to a customer.

**MRP (Material Requirements Planning)** A computational procedure for converting a multiperiod forecast of finished good demand for all our products into a production plan for every sub-assembly and component that goes into our finished products by, a) "exploding" a BOM for each product and sub-assembly into requirements for lower level sub-assemblies and components, b) spreading these derived demands backwards in time using estimated lead times, and c) netting out existing inventories to get the net amount needed to be put into production each period of each sub-assembly.

**MRP II** (Materials Resource Planning-II) A generalization of MRP to include financial aspects of the production process, as well as some attempts at taking into account capacity. See also ERP.

**MTBF**: Mean Time Between Failures. This measure does not include repair times. E.g., suppose a machine works properly for six weeks, then fails and needs one week to repair, then works properly for six weeks, then fails and needs one week to repair, etc. Its MTBF is six weeks, not seven. See also IFR, DFR, and bathtub curve.

**multi-echelon**: multi-level, as in manufacturer, distributor, retailer.

**Multi-modal**: Using more than one mode of transportation, most commonly picked up from the shipper in a trailer truck, the trailer is then carried piggy-back on a train and then again the final step, the trailer is pulled behind a tractor.

**NAFTA** (North American Free Trade Agreement): An agreement among Canada, the U.S., and Mexico, taking effect 1 January 1994, to gradually eliminate all tariffs among the three countries over a 15 year period. It is expected that truck carriers from any one of the nations will be able to transport goods between any origin-destination in the three countries. It also sets standards for each country on related issues such as pollution, and tariffs with nonmember countries. See: <http://www.nafta-sec-alena.org>.

**NAPM** (National Association of Purchasing Management): An association dedicated to the education and advancement of purchasing and supply management professionals, see <http://www.napm.org>. Effective 1 January 2002, its name was changed to the Institute for Supply Management.

**Nash equilibrium**: a situation in which no player (e.g., supply chain partner) can improve his utility unilaterally. It need not be Pareto optimum. See Stackelberg equilibrium.

**nautical mile**: 6076 feet=1852 meters, as opposed to 5280 feet in a regular mile.

**Nesting**: in two-dimensional cutting stock problems, the process of deciding how to fit required finished good shapes into (typically rectangular) sheets of raw material, so as to make most efficient use of the raw material. It occurs in textiles when cutting things like pant legs and pockets from raw fabric; in woodworking, and in the manufacture of products from sheet metal.

**Network effect**: See Metcalfe's Law.

**Newsvendor Problem**: Historically also known as the newsboy problem, it is the simplest inventory planning problem under uncertainty. Nevertheless, the essence of the solution to this problem is widely used in such areas as yield management in the air lines, and inventory setting by catalog merchants. The setting is a one period problem in which one must choose how much inventory to stock of a single product in the face of uncertain demand. If  $c$  = purchase cost/unit,  $v$  = revenue per unit sold,  $h$  = holding charge/unit left over, and  $p$  = explicit penalty/unit of unsatisfied demand, then the newsvendor ratio is  $R = (p + v - c) / [(p + v - c) + (h + c)]$ . The stock level,  $S$ , should be chosen, so that the probability of not stocking is  $R$ .

**nexus**: Essentially, a firm is said to have nexus in a state if the firm has an office or physical presence in the state. States that have a sales tax require that a firm that has nexus in the state, collect sales tax (and remit to the state) on all sales to customers in the state. See also: use tax.

**NHTSA** (National Highway Traffic Safety Administration): A division of the DOT in the USA. One of its duties is to administer fuel economy (CAFE) standards.

**NIST** (National Institute of Standards and Technology): An agency, <http://www.nist.gov>, of the U.S. Department of Commerce. It administers four major programs: 1) Measurement and Standards, 2) Advanced Technology, 3) Manufacturing Extension Partnership, and 4) Baldrige National Quality Award.

**Nonconstant sum game**: A situation involving two players (or firms) in which they can increase their total profits if they cooperate. This is in contrast to a zero or constant sum game. In either case, there is still the sometimes vexing problem of how to split the profits.

**Normal distribution**: a distribution that tends to be a good representation of the sum of a lot of independent random variables. It has two parameters, a mean  $M$ , and a standard deviation,  $s$ . If you

define  $z = (x-M)/s$ , then its p.d.f. is:  $\exp(-z^2/2)/2.506628275$ . In the LINGO modeling language, the c.d.f. is given by @PSN (  $z$  ) .

**NP-hard:** A class of problems is NP-hard if there is no known method for solving a problem from this class such that solution time increases at worst as a polynomial in the problem size. Typically, solution time may grow exponentially with problem size.

**NVOCC (Non-Vessel-Owning Common Carrier):** In ocean transportation, an NVOCC is an intermediary who arranges shipping for small or inland shippers. The NVOCC buys transportation from carriers at bulk rates and then resells it to small shippers. The NVOCC gets a standard Bill of Lading from the carrier. The NVOCC gives a "House Bill of Lading" to the shipper. At the destination, the NVOCC reclaims the bulk shipment with the regular Bill of Lading. After deconsolidation, the shipper or his customer claims his portion of the shipment with the House Bill of Lading.

**OEM (Original Equipment Manufacturer):** A manufacturer is an OEM if its product is used a component in the product of some other manufacturer.

**OLAP (OnLine Analytical Processing):** A general term for database queries where some analytical calculations are performed in addition to the data retrieval. For example, computing total sales by time period, or by geographic region, or by product class might be considered a simple form of OLAP.

**OLTP (On Line Transaction Processing):** The processing of simple queries or lookups against a typically large database. The On-line part means there is an emphasis on short response time, such as when a customer is looking up the status of an order.

**Order fill rate:** the fraction of orders for which every line is filled. This measure is important, for example, if all SKU's in the order are needed by the customer to complete the repair of a piece of machinery.

**OSHA (Occupational Safety & Health Administration):** An agency under the U.S. Department of Labor that sets and enforces standards for workplace safety. See <http://www.osha.gov>.

**OTI (Ocean Transportation Intermediary):** See NVOCC.

**Outbound:** Shipment out of a DC. Tends to be on smaller vehicles.

**Outsourcing:** The hiring by firm  $X$  of an outside firm  $Y$  to perform some activity  $Z$  that might otherwise be performed by  $X$ . Examples of such activities are shipping/transportation, computing services, payroll accounting, etc. Justifications for outsourcing are: a) there are economies of scale that can be enjoyed by  $Y$  because it serves many firms in addition to  $X$ , and b) there is little likelihood of  $X$  getting a competitive advantage by doing activity  $Z$  extremely well, c) firm  $X$  is expanding quickly and it can get the capability for doing activity  $Z$  from firm  $Y$  much more cheaply than it can develop its own capability. For example, payroll accounting requires one to be familiar with all the details of municipal, state, and federal tax withholding. A payroll accounting firm can spread the cost of maintaining this familiarity over all its clients. It would be inefficient for each client to invest in staying current on tax law. The economies of scale can also be statistical. E.g., if  $X$ 's need for the activity varies significantly over time, firm  $Y$  can handle these fluctuations more efficiently if it is providing the activity for a number of firms.

**Overbooking:** The process of selling more capacity than one has available, in the expectation that some of the customers to whom capacity has been committed, will cancel or not show up. Overbooking is widely used in airline and hotel reservations. No-show rates as high as 20% are not unusual, so if overbooking were not used, capacity could be significantly underused. The basic marginal analysis that is done in deciding upon the level of overbooking is that one should sell an additional unit of capacity if the expected net revenue is positive. That is, one should sell a reservation to customer  $X$ , if (immediate revenue from  $X$ ) > Prob { $X$  in fact shows up} \* Prob {capacity will be oversold} \* (penalty for not being able to serve the customer  $X$ ).

**Pallet:** Platform, usually of wood, about 6 inches high by 40 in. by 48 in. on which goods are placed, so they can be picked up by a forklift to be placed in storage or on a truck. These dimensions allow two pallets to be placed side by side in a standard U.S. truck trailer. In Europe, a pallet size of approximately 48 in. by 32 in. is sometimes used. More recently, plastic based pallets have been introduced. Although more expensive, they last longer and have less danger of carrying dangerous

insects from one part of the world to another. In order to prevent the spread of pests, some countries require wood pallets to be treated at 56 degrees centigrade and or fumigated with methyl bromide. Plastic pallets can be made in shapes that allow nesting of empty pallets (i.e., nesting pallets can be stored one on top of the other, so that the vertical height of the stack of, say ten, nesting pallets is considerably less than ten times the height of a single pallet). In flexible manufacturing, the term “pallet” is sometimes used to denote a metal plate for carrying various products along a production line. Each product manufactured on the line (e.g., motorcycle engines and small car engines) has its own pallet type. All pallets have the same interface on the bottom, so that all products can be carried down the line and mounted on the same standard fixtures.

**Palletize:** process of placing goods on a pallet and fastening them in some fashion (e.g., with shrink wrap), so that the assembly is stable during shipment.

**Palm’s Theorem:** If a base stock inventory policy is used, and demands per unit time have a Poisson distribution with mean  $D$ , and lead times are i.i.d. with mean  $L$ , then the distribution of items on order at any randomly chosen instant is Poisson with mean  $D*L$ .

**Pareto Analysis:** A sorting of objects according to their volume, size, rate, etc. A typical result is that a small fraction of the objects (e.g., 15%) constitute a majority (e.g., 85%) of the total volume. See also, ABC analysis.

**Pareto Optimum:** an allocation of something (e.g., total profit in a supply chain) such that there is no other allocation in which each player does at least as well, and at least one player does strictly better.

**p.d.f.:** probability density function. A mathematical function or curve such that the probability that a random variable falls between two values  $x$  and  $y$  is equal to the area under the curve between  $x$  and  $y$ .

**PDF 417 code:** A 2 dimensional, laser scannable code used to store up to 1100 characters of information. The code is used for supply chain purposes in the automobile industry and by the U.S. department of defense. Some states use it to store information on driver license cards. Other 2-D codes are Data Matrix code and MaxiCode. For more details, see [www.aimglobal.org](http://www.aimglobal.org).

**Peak load pricing:** The practice of setting a higher price for demand that occurs when a production facility is running at capacity. In the electrical industry, a customer may have to pay an additional charge based on the peak amount of electricity used during a day or month. The purposes of peak load pricing are: a) to help pay for the capacity that the supplier must add to handle the peak load, and b) to motivate the users to smooth their demand or move their demand to non-peak periods.

**PERT (Program Evaluation and Review Technique):** A project management technique similar to CPM but with additional features to represent random activity times. First used to manage Polaris Fleet Ballistic Missile program.

**PGP (Pretty Good Privacy):** A widely used, “open” public key encryption system. See:

Garfinkel, S.(1995), *PGP:Pretty Good Privacy*, O’Reilly&Associates, ISBN 1-565920988. The technology is similar to RSA.

**Phillips curve:** The relationship, conjectured and observed by A. W. Phillips, that there tends to be a tradeoff between unemployment and inflation. That is, low unemployment tends to be associated with inflation.

**Picking:** the process of picking items from storage to satisfy today’s orders. It may occur at several levels, such as picking a full pallet, picking a case (for satisfying an order from a retailer) from a pallet, or picking an individual item (for satisfying retail demand) from a case. See, for example, pick-to-light and bucket brigade.

**Pick-to-light:** A warehouse that uses a pick-to-light system has a small electronic display, typically including a light, next to each storage slot. A central computer will display which items are to be picked (via the light) and how many (on the display). There is typically a button that the picker can push to turn off the light to indicate to the computer that the proper number have been picked.

**Piggy back:** Multi-modal transportation in which product is loaded onto a highway trailer; a tractor hauls the trailer to a rail yard. The trailer is loaded onto a special flatcar. The flat car is hauled in a train to near the product destination and the process is reversed. Good for high volume product where speed is not so important.

**Pipeline inventory:** product on order. Sometimes also defined to be on-hand + on-order.

**Planogram:** A plan for locating products on retail shelves, grocery stores in particular. It is based on such ideas as: high demand items should be placed at eye-level. Items for children are placed at a lower level. Similar products should be together. Complementary products (e.g., pancake mix and pancake syrup) should be together. Higher demand and higher profit products should get more shelf space, etc.

**PO (Purchase Order):** A request by a buyer to a seller to ship a certain number of each of a list of SKU's. Each SKU on the PO is typically called a line item.

**Poisson distribution:** a distribution, which tends to be a good approximation of retail demand in a specified time interval (e.g., the number of calls into a call center in a specific hour). If the mean demand is  $D$ , then the probability of  $k$  demands, for  $k = 0, 1, 2, \dots$  is:  $(e^{-D} D^k)/k!$ . The standard deviation is the square root of  $D$ . As  $D$  becomes large, the Poisson distribution converges to the normal distribution. The approximation is good for, say,  $D > 15$ . The binomial distribution with parameters  $n$  and  $p$ , converges to the Poisson as  $n$  gets large and  $n*p$  converges to  $D$ .

**POS (Point Of Sale data):** data typically accumulated by retail scanners. Users of these data have up to the minute information on how much of what product was sold when and at which outlet.

**Postponement:** A modification to a production and distribution process, so that some operation on the product is done later in time and closer to the final customer. Typically there are two motivations: a) less inventory needs to be carried earlier in the process because of risk pooling, and b) transportation costs may be reduced because the not-quite-complete product ("some assembly required") is easier to transport.

**PPI (Producer Price Index):** A collection of over 10,000 indices of selling prices received by domestic producers of goods and services. Long term contracts may sometimes have a price escalation clause based on a particular PPI. It is compiled by the U.S. Bureau of Labor statistics, <http://stats.bls.gov> and usually published at the end of the second full week of the month. Both seasonally adjusted and unadjusted versions are available. See also, CPI.

**Predictive dialing:** A technique used in outbound telephone call centers to increase the utilization of the operator personnel staffing the phones. The predictive dialing system keeps track of a) how long each current call has been in process, and predicts when the next agent will be free, and b) what is the probability that the next dialing attempt will get a "live" answer rather than a busy signal, or no answer. Taking all this into account, it automatically starts dialing the next number to be called such that just as an agent becomes free a "live" person being called will pickup the phone. The statistical theory is much like the overbooking process in airline reservations.

**Prisoner's dilemma:** A situation in which two players (e.g., retailers) both make substantial profit if they "cooperate" (e.g., spend moderate amounts on advertising and keep the price high). This is an unstable equilibrium, however, if there is a strong temptation to "cheat" (e.g., obtain more profit for oneself by unilaterally dropping the price and advertising heavily). The situation when both players "cheat" is a stable equilibrium (i.e., neither player is willing to change his decision by himself, however, each player makes less profit than he would if both players cooperated). The term comes from the setting where two accomplices in crime are held prisoner. Each is offered to be set free if he supplies incriminating evidence against the other. Both will receive a light punishment if neither supplies evidence. If one refuses to cooperate but the other supplies evidence, then the uncooperative one receives a severe sentence. This is an example of a nonconstant sum game.

**Probit model:** A statistical technique frequently used in deciding whether to grant or deny credit to a prospective customer. Identical to the Logit model except that the Normal distribution, rather than the Logistics distribution is used to estimate the probability the prospect is bad.

**Promotion:** a temporary price reduction, typically publicized or “promoted” with advertising. There seem to be two reasons for promotions: a) seller is trying to reach a sales quota (e.g., for the current quarter) or b) it is a way of doing value based pricing. E.g., if one week out of four the price is lowered, customers who are only willing to pay the low price will wait three weeks to buy their needs for all four weeks, whereas, customers who are price insensitive will pay the high price three times out of four. See: EDLP,

**Public key encryption:** A two key encryption system whereby the sender uses his private key to encrypt his message (e.g., a PO). His public key, known by all his business partners, is needed to decipher the message. Thus, a recipient of a message is able to verify the source of a message. It also allows the sender to prevent a message from being read by anyone but the intended recipient by encrypting it with the recipient’s public key. The recipient can then decipher the message with his private key. This provides one way of implementing one form of an extranet.

**Pull system:** A multi-echelon system in which the individual levels use a Q,r inventory policy to request product from their supplier. Q should be small. Pull systems, as opposed to Push systems, are considered “good” or politically correct.

**Push system:** A multi-echelon system in which a central planner forecasts needs at individual levels and “pushes” product to these levels in advance of the demand. See also: pull system. If forecasts are perfect a push system is very good. If forecasts are bad, it may be really bad.

**QFD (Quality Function Deployment):** A table oriented procedure for converting customer requirements for a product into the features or functions that should be included in the product design.

**Quantity discount:** Pricing policy by which the cost per unit purchased decreases with the quantity purchased. Two main types of discount are: a) “all units”, in which case the lower price applies to all units purchased if the quantity purchased exceeds the threshold, and: b) “incremental units”, in which case the lower price applies only to units purchased in excess of the threshold. Another variation that is useful if a variety of products are being purchased from a single vendor is to base the discount upon the \$ amount purchased, rather than the number of units. See also bundle pricing.

**Q,r:** An inventory policy under which, when the inventory level drops to r, an amount Q is ordered from the supplier. It is an extension of the EOQ inventory policy.

**Quote:** A promise by a supplier to a prospective customer of a price at which it will supply a specified good or service. The promise usually has a quantity, an expiration date, and a location at which the product will be made available. See also: RFQ.

**R<sup>2</sup> (R squared):** A measure, between 0 and 1, of how well a forecast or regression line fits a set of data. An R<sup>2</sup> of 1 means a perfect fit. Numerically, it is  $1 - (\text{sum of squared errors about the forecast line}) / (\text{sum of squared errors about the mean})$ .

**Rain-check:** A form of backlog in which the seller, in the event of a stock-out, gives a ticket to a customer wishing to purchase the product, guaranteeing that the seller will order more of the product and sell it to the customer at the original price.

**Ramsey prices:** A form of cost allocation that may be of interest when there is a high fixed cost of producing, but a low marginal cost per unit produced. If you want users to make optimal use of goods, you want to charge them the marginal cost. If this were done, however, then the producer would show a loss. If a producer can charge different prices to different markets or departments, and we have the demand curve for each market, as well as the production cost function, then Ramsey prices are the solution to the problem:

Maximize the value of the goods delivered minus the cost of producing them,  
Subject to:  
Revenue from the goods sold  $\geq$  cost of producing them.

**Reefer:** Refrigerated container, trailer, or truck.

**Reneging:** The action of a customer in a waiting queue to depart prematurely resulting in a lost sale. Contrast this with balking.

**Revenue management:** a collection of techniques for increasing the revenue from the sale of a product. The most notable technique is to charge more to customers who are willing to pay more. For products that “expire” such as airline tickets for a particular flight or hotel reservations for a particular night, typical method is to sell a restricted number of units at a low price and the remaining units at a high price. Customers who are willing to pay more are typically the ones who realize only at the last minute, when all the cheap units are sold out, that they have a need for the product. For a product that does not expire, but has a well defined “birth”, price might be changed in reverse fashion. Start with a high price, which will be paid by customers who urgently need the product, and then gradually lower the price for less urgent customers. See also: yield management, value based pricing, discriminatory pricing.

**Reverse auction:** An RFQ process in which prospective suppliers submit their quotes, typically via the internet, to the buyer. The process may be open, so that all suppliers can see what is the current winning (lowest) quote.

**Reverse logistics:** the management of product and packing materials when the customer no longer needs them. For a retailer, it may mean how to handle returns when the customer fairly quickly discovers he bought the wrong product. For a manufacturer, it may mean figuring out how to reuse a product, or else how best to dispose of the product if it is not reusable.

**RF (Radio Frequency):** In warehouse operations a system that uses a portable, typically hand held, device that is in radio communication with a central computer. The portable device has a scanner, a multi-line display and some memory. For example, the computer can transmit pick instructions to the display. The scanner can transmit data back to the computer regarding the item picked. In the U.S., the transmission is typically at either 900 MHz or 2.4 GHz.

**RFID (Radio Frequency IDentification):** A type of label or badge that is read electronically rather than optically. The reader need not touch the label in order to read it. Typical storage content is 126 bits of information. Some RFID labels are re-writeable. That is, new information can be inserted. The cost/label is higher than that of a printed bar code label. Some tags contain their own battery power, whereas more commonly they are simply transponders. That is, they return a signal after being energized by a reader. In the U.S., the communication with the tag tends to be in the 915 MHz band. Outside the U.S., it is typically in the 13.56 MHz band.

**RFM (Recency, Frequency, and Monetary value) model:** A scoring system for customers that gives a high score to a customer who bought something recently, or who bought a large number of times over a sample period (e.g., the last two years), or whose average purchase amount was high. A simple assumption is that a customer with a high RFM score is a good candidate to receive further solicitations. See also, CRM.

**RFQ (Request For Quote):** A document that a prospective buyer sends to prospective suppliers asking them to submit a quote for how much they will charge the buyer for a specified good or service. The RFQ may specify several different quantities that might be purchased, and a due date by which the quotes or bids must arrive at the buyer. A supplier is expected to submit a price/unit for each quantity. See also: Reverse auction.

**Right-to-work law:** Law in some states allowing a worker at a unionized plant to work permanently at the plant without belonging to the union.

**RO-RO (Roll On Roll Off):** Ship on which cargo vehicles can be driven on or off.

**Routing:** the process of deciding the sequence of stops to be made by a vehicle.

**RSA:** a public key encryption system developed by Rivest, Shamir, and Adleman and marketed by RSA, Inc. It is based on the fact that there is no known fast way of finding the factors of a large integer (e.g., one with several hundred digits).

**Safety stock:** Inventory carried to protect against running out during a lead time due to the uncertainty in either: the length of the lead time, the amount delivered, amount demanded, or time of occurrence of demand during a lead time.

**Same store sales:** sales this year in stores that were open last year.

**Say's Law:** In simplest form, this is the “build it and they will come” philosophy—the belief that supply creates demand (e.g., if we produce a product, people will realize that they would like to buy it). If we build a sports stadium, sports teams and spectators will come. Attributed to Jean Baptiste Say, circa 1800.

**SCADA (Supervisory Control and Data Acquisition):** A system, and to some extent standards, for monitoring and controlling remote equipment, such as a manufacturing plant, a pipeline network, or an electric power distribution system. Remote meters can be read electronically, and then commands can be sent to various machines (e.g., switches) to tell the machines to do some action.

**Scanner:** a device for reading a product label such as a bar code.

**SEC (Securities and Exchange Commission).** A U.S. agency that has five Commissioners appointed by the President, with the advice and consent of the Senate. The official mission of the SEC is to protect investors and maintain the integrity and honesty of the securities markets. See <http://www.sec.gov>.

**Shadow price:** see dual price.

**Shapley value:** A method of cost allocation that is useful when the total cost of providing some service to a group of players or firms is less if the players cooperate. Suppose customers *A*, *B*, and *C*, are each to receive a delivery from a single truck that makes one trip to serve the three. How should the cost of the trip be allocated? The Shapley value allocates cost to a given customer based upon the average marginal cost of adding that customer to the trip/coalition, where the average is taken over all possible permutations of how customers/players could be added to the trip/coalition. Suppose the cost of delivering to any combination of the three is as follows: *{A}*: \$88, *{B}*: \$91, *{C}*: \$90, *{A,B}*: \$150, *{A,C}*: \$148, *{B,C}*: \$151, *{A,B,C}*: \$180. E.g., making a single trip to just *A* and *C* costs \$148. Making one trip that serves all three costs \$180. The six possible permutations and the marginal cost of each customer are:

Permutation	<i>A</i>	<i>B</i>	<i>C</i>
<i>A, B, C</i>	\$88	150-88 = \$62	180-150 = \$30
<i>A, C, B</i>	\$88	180-148 = \$32	148-88 = \$60
<i>B, A, C</i>	150- 91 = \$59	\$91	180-150 = \$30
<i>B, C, A</i>	180-151 = \$29	\$91	151-91 = \$60
<i>C, A, B</i>	148- 90 = \$58	180-148 = \$32	\$90
<i>C, B, A</i>	180-151 = \$29	151- 90 = \$61	\$90
Shapley value (average)	\$58.5	\$61.5	\$60

See also: core of a game.

**Shipper:** The firm or person who needs to have material shipped (e.g., a manufacturer). In contrast, see carrier.

**Shrink wrap:** A plastic wrap that tends to shrink after stretching, and adheres to itself, that is wrapped around a skid to keep it intact during shipment.

**Shrinkage:** catch-all term for the common situation whereby the physical inventory is less than what inventory records claim. Most common causes are theft, loss, storage in the wrong location, delivery to the wrong store, breakage, etc.

**SI units:** An internationally agreed upon system (Système International d'Unités) for measuring physical quantities. There are seven base units: meter(m) for length, kilogram(kg) for mass, second(s) for time, ampere(A) for electric current, kelvin(K) for temperature, mole(mol) for amount of substance, and candela(cd) for luminous intensity. There are 21 derived units, such as newton(N) for force(kg\*m/s<sup>2</sup>), joule(J) for work(kg\* m<sup>2</sup>/s<sup>2</sup>), and watt(W) for power(m<sup>2</sup>\*kg/s<sup>3</sup>). Standard prefixes for successively larger/smaller units are: deka(10), hecto(10<sup>2</sup>), kilo(10<sup>3</sup>), mega(10<sup>6</sup>), giga(10<sup>9</sup>), tera(10<sup>12</sup>), peta(10<sup>15</sup>), exa(10<sup>18</sup>), deci(10<sup>-1</sup>), centi(10<sup>-2</sup>), milli(10<sup>-3</sup>), micro(10<sup>-6</sup>), nano(10<sup>-9</sup>), pico(10<sup>-12</sup>), femto(10<sup>-15</sup>), and atto(10<sup>-18</sup>). For more information, see <http://physics.nist.gov/cuu/Units/units.html>.

**SIC code:** Standard Industrial Classification. A six digit code used for classifying industry in the U.S. For example, 484xxx is trucking in general; 484121 is long distance FTL; and 484122 is long distance

FTL. SIC is being replaced by a common North American code, NAICS, which will be applicable to Canada, the U.S., and Mexico. See <http://www.census.gov/epcd/www.naics.html>.

**Six Sigma:** A quality management approach that concentrates on keeping the percentage of defectives low. Numerically, the six sigma standard is frequently stated as a fraction defective of about 3.4 defects per million. This sounds low, but note that for some industries, such as airline travel, this level of quality would still be unacceptable (e.g., contemplate an airline that has almost four crashes per million flights). W.r.t. the Normal distribution, 3.4 defects per million in fact corresponds to only 4.5 sigma or standard deviations. That is, quality control of the process should be so precise, so the upper and lower limits for acceptable values fall at 4.5 sigma of the production process. Thus, there is a 1.5 sigma shift in the mean allowed.

**SKU (Stock Keeping Unit):** A distinguishable product. E.g., mushroom soup/10 oz., mushroom soup/20 oz., and tomato soup/20 oz., constitute three different SKU's.

**Skid:** A pallet with product stacked on it, for a specific customer or from a specific supplier.

**Slip sheet:** a sheet of heavy plastic or fiberboard placed under a bundle of material such as cases of grocery items. A slip sheet may be used to separate layers on a pallet, or may be used as an alternative to a pallet. As an alternative, its major advantage is that it saves space, approximately 15 cm (6 in.) of vertical space. Its disadvantage is that it is not as easy to handle by a standard forklift as a standard pallet load.

**Slip streaming:** The practice of making unannounced product changes, especially in software. The typical setting is that a small bug or design flaw is discovered and then corrected while production continues. This introduces possible maintenance problems, in that if repairs are required, the repair person must be able to identify which version of the product is involved (e.g., by serial number). There may also be customer discontent if early customers feel that the differences between the different versions are noticeable. The advantage of slipstreaming is that new customers immediately benefit from the improvement.

**Slotting:** The processing of deciding where each product gets stored in a warehouse. For example, high volume SKU's should be close to the shipping door. SKU's that tend to get demanded together might be stored near each other. See also, Planogram.

**Slotting fee/allowance:** A fee charged by some retailers to suppliers who wish to have their product carried on the retailer's shelves. This is typically used when the retailer feels that the probability of low demand for the product (typically a new one) might cause the product to be less profitable than other products the retailer carries. A powerful retailer might also use it as a means for trying to get a discount from a supplier who does not want to, at least officially, give selective discounts.

**Slurry:** a suspension of a solid, such as pulverized coal, in a liquid such as water so that the solid may be shipped by pipeline.

**SMED (Single Minute Exchange of Die):** A philosophy and methodology developed by Shigeo Shingo for Toyota for the fast changeover of a machine from production of one product to the production of another. The phrase "single minute" is slightly misleading because Shingo really meant "single digit" (i.e., he interpreted any changeover of 9 minutes or less as a single minute exchange). Changeover times that once were several hours were reduced to minutes. The benefits of short changeovers are numerous. The most immediate benefits are that short production runs become more economic, and thus inventories are lower, and one can respond more rapidly to changing customer demands. The methods include: a) offlining: converting steps of the change-over offline, so that the production process can continue running while preparations for the changeover are made, b) quick connectors: rather than laboriously unscrewing and tightening bolts, quick fasteners such as cams and "slip on and tighten" key-hole connectors are used.

**Sortation system:** an important device in an automated distribution or baggage system. It typically consists of a long conveyor belt with a scanner at the front end. As packages enter the front end, a scanner reads a destination label on the package. The system then pushes the package off the conveyor at an off ramp appropriate for the package's destination.

**Sorting:** A major function provided by a DC, specifically, collect all the items destined for a particular customer and group them together for shipment.

**SPC** (Statistical Process Control): See Control chart.

**Split sourcing:** Serving a customer or need from two or more sources, usually because of limited capacity at one of the sources. Might also be used for reliability reasons in case one source is unreliable. Administrative costs tend to be higher with split sourcing. With single-sourcing, a customer can contact his supplier directly for replenishments. Under split sourcing there must be a higher coordinating authority to decide which orders are satisfied from which source.

**Stackelberg equilibrium:** if there are multiple Nash equilibria, one in which the utility of one of the players, the “most powerful” or leader, is maximized.

**STB** (Surface Transportation Board): U.S. federal agency that has replaced some of the regulatory functions of the former ICC. It is responsible for the economic regulation of interstate surface transportation, primarily railroads. See <http://www.stb.dot.gov>.

**sunk cost:** a cost which is no longer avoidable.

**Supply Chain:** see channel.

**T1 line** (Trunk level 1): A data transmission capacity of 1,544,000 bits per second. This is a standard measure of telephone line capacity in North America. Historically, enough to carry 24 voice channels. Higher levels are: T2: 96 voice channels. T3: 672 voice channels. T4: 4032 voice channels.

**Tank car:** Rail car for carrying fluids. In contrast, see box, flat, and hopper car.

**Tare weight:** weight of empty vehicle, perhaps with driver, used for computing weight of delivered product.

**TEU** (Twenty foot Equivalent Unit): A unit of measure for maritime freight containers. The majority of maritime containers are either 20 feet or 40 feet long, 8.5 feet high, and about 100 inches wide. A 40 ft container is 2 TEU.

**TIGER** (Topologically Integrated Geographic Encoding and Referencing): a set of files available from the U.S. Bureau of the Census (<http://www.census.gov>) that give the latitude and longitude of major physical objects in the U.S. These include a) line objects such as roads, railroads, rivers, and utility lines; b) boundaries of objects such as counties, school, and congressional districts; and c) landmarks such as churches, schools, parks, cemeteries, buildings and factories. Address ranges for most streets are also available.

**TMS** (Transportation Management System): Software for helping manage the transportation, typically outbound from a distribution system. If, for example, outbound shipments are LTL, the TMS might provide the route. That is, the sequence of stops, and the order in which material is to be loaded onto a truck.

**TOC** (Theory of Constraints): A managerial philosophy that stresses the importance of identifying the capacity bottlenecks of a production process and then either eliminating these bottlenecks and/or finding ways to better utilize these bottleneck facilities. Although it is not computational, in spirit it is somewhat similar to LP.

**TOFC** (Trailer on flatcar): See piggy back.

**Tolling:** Contract manufacturing. Hiring some other manufacturing firm to do part or all of the manufacturing of your product. The contract manufacturer never owns the product.

**Tornado diagram:** A method for displaying the effects of various uncertain parameters on an output measure such as profit. If we are contemplating the development of a new product, uncertain parameters might be market size, production cost per unit, selling price, and development cost. For each parameter, you estimate three values: a most likely value, a lowest plausible value, and a highest plausible value. If there are  $n$  parameters, you then evaluate  $2n + 1$  cases, namely, the base case in which all parameters are set to their base value, and then for each parameter  $i$ , while holding all other parameters at their base value, evaluate total profit when parameter  $i$  is at its low

value and when it is at its high value. Finally, you display the results as a horizontal bar graph in which profit is plotted horizontally and the parameters are listed vertically. For each parameter, a bar is displayed showing the range in total profit. If the parameters are sorted from top to bottom by greatest range in output to smallest range, then the diagram looks like a tornado or funnel cloud. A limitation of a tornado diagram is that it does not reveal interactions between parameters.

**Tote:** a container or box, small enough to be carried by a person, into which a picker places items as they are picked in the warehouse, typically one order per tote.

**TQM (Total Quality Management):** A philosophy of management of quality that takes a comprehensive, high-level view of quality improvement.

**Tradeoff curve:** A curve showing the tradeoff between two measures of goodness (e.g., low inventory vs. number of stockouts). See also efficient frontier.

**Transactions based costing:** See ABC (activity based costing).

**Transfer price:** an internal price used when one profit center of a firm provides goods or services to another profit center of the firm. The purpose of transfer prices is to motivate the individual profit centers to behave optimally with respect to the whole firm. See also: incentive compatible. Roughly speaking, when a production facility is running at capacity, the transfer price of its output should be the cost of buying the equivalent output in the outside market. When a production facility is running under capacity, its transfer price should be the marginal cost of production. Tax considerations may also play a role when the two parties involved in a transfer are in different taxing jurisdictions. Very similar to dual or shadow prices in an LP.

**Transshipment:** movement of product between two facilities at the same level in a supply chain, as when one automobile dealer supplies another dealer with a car.

**TSP (Traveling Salesperson Problem):** The problem of finding the shortest tour of a set of cities such that each city is visited exactly once. It is NP-hard. The same kind of problem arises in production changeovers among various products (e.g., in a paint booth).

**Tunnel scanner:** A tunnel scanner has individual scanners on top, both sides, and perhaps even the bottom of a conveyor, so that a package label can be read regardless of its orientation. This reduces the amount of labor required to make sure a package is properly oriented as it enters a sortation system.

**Turnover:** outside the U.S., it is the sales, typically measured in monetary units. In the U.S., it is usually short for turnover rate of inventory, the number of times per year that old inventory is replaced by new inventory = (sales per year)/inventory.

**Two dimensional code:** A code for marking product in which dots over an area, rather than bars in a row, are used to code information. It can hold much more information (e.g., 200+ digits or 100+ characters, vs. typically 12 digits for a bar code).

**UCC (Uniform Commercial Code):** a standard set of laws governing commercial transactions (bills of lading, letters of credit, bank deposits, collections, etc.) adopted by all states in the U.S. except Louisiana (it uses a variant of the Napoleonic code).

**UCC (Uniform Code Council):** An industry group to promote multi-industry standards for product identification or bar codes. See <http://www.uc-council.org>

**ULD (Unit Load Device):** A cargo carrying container of standard size, usually in the airfreight industry. These can be carried by most large aircraft, but not by smaller aircraft such as the B737 or the MD80.

**Ullage:** Unfilled space at the top of a storage tank, perhaps filled with inert gas.

**Unit train:** train, typically for hauling coal, used for repeated hauls, so that cars in it are never disconnected.

**Unitization:** the process of bundling a collection items (e.g., cases) together, as on a pallet, mainly to simplify transportation. Similar to containerization or palletization.

**UPC (Universal Product Code)** A 10 to 12 digit machine readable numeric product code originated in the food industry. The first several digits represent the manufacturer, the remaining digits the product. See also bar code, GTIN.

**Use tax:** A tax by a state on purchases by a firm in the state on purchases from an out-of-state supplier. The use tax rate is generally identical to the state sales tax rate on the item. Generally, individuals disregard a state's request to pay sales tax on out-of-state purchases. State legislators introduced the use tax to enforce this request on firms (who do not vote). See also nexus.

**Value based pricing:** charging each customer an amount close to the customer's value for the product. This presumes that resale among customers does not occur and that one can determine each customer's value for the product. One form originally used by Brown Shoe Company, then IBM, and then Xerox, was metering. Brown and IBM charged by hours used. Xerox charged by copies made. See revenue management, discriminatory pricing, and promotion.

**Value Engineering:** a cost reduction philosophy based on carefully identifying the true purpose of any component in a system and then finding the cheapest yet acceptable way of fulfilling that purpose.

**VAN (Value Added Network):** A third party provider of network services, such as EDI capability, to buyers and sellers.

**VAR (Value Added Reseller):** A firm that sells a product bundled with some additional features (e.g., installation) that tend to be customer specific. E.g., a user of the Oracle database may buy the Oracle software from a VAR who installs it on the customer's computer.

**Variables sampling:** In quality assurance, sampling in which quality is measured along a continuous interval (e.g., diameter, weight, strength, etc.). In contrast, see attributes sampling.

**Variance:** 1) A measure of the variability of a set of data (e.g., sales per week). If we have a sample of  $n$  observations,  $x_i$ , for  $i = 1, 2, \dots, n$ , and  $\bar{x}$  is the mean of the sample, then the sample variance is  $\sum_i (x_i - \bar{x})^2/n$ . Sometimes an algebraically equivalent, but numerically less accurate formula is suggested:  $\sum_i x_i^2/n - \bar{x}^2$ . When the variance is small relative to the mean, the latter formula can be very inaccurate. Thus, it should be avoided. Nevertheless, some popular spreadsheet programs use the less accurate version. The sample variance is a biased estimate of the population variance. That is, the variance as  $n$  approaches the population size. The sample variance underestimates the population variance because the squared differences are taken with respect to the sample mean,  $\bar{x}$ , rather than the (generally unknown) population mean. If the population size is infinite, then an unbiased estimate of the population variance is  $\sum_i (x_i - \bar{x})^2/(n - 1)$ . A useful result when dealing with the sum of two random variables (e.g., the pooled demand of two similar products) is that:

$$\text{Variance}(D_1 + D_2) = \text{Variance}(D_1) + \text{Variance}(D_2) + 2 * \text{Covariance}(D_1, D_2).$$

2) In accounting, a variance is the difference between actual and that predicted by standard.

**VAT (Value Added Tax):** A tax, common in Europe, applied at all levels of the supply chain on the difference between what a producer charges for his product and the cost of all the inputs to the product. In contrast, a sales tax is applied only at the retail point to the full price the seller/retailer charges for product.

**Vertical integration:** the ownership by a single company of several levels in the supply chain. For example, in the 1920's Ford owned both steel mills and car factories. See also Coase's Law.

**Vickrey auction:** A sealed bid auction in which the higher bid(s) wins, but the winner(s) pay the price of the highest unsuccessful bid. This produces approximately the same result as an open, rising price auction. The desirable feature of a Vickrey auction is that bidders have the incentive to bid their true value for the product. See Vickrey, W. (1961), "Counterspeculation, Auctions, and Competitive Sealed Tenders", *Journal of Finance*, vol. 16, no. 1(March), pp.8-37. In contrast, see also: Dutch auction.

**VMI (Vendor Managed Inventory):** An inventory management policy whereby the supplier decides when to restock product at his customer's site based on up-to-the minute usage information from the customer. This allows the supplier to take into account his own costs of restocking (e.g., fixed costs of restocking) shared costs when restocking several nearby customers, etc. These agreements typically

include a penalty to be paid by the supplier if there is a stockout, and an upper limit on how much inventory can be carried at the customer. The payment arrangement may allow the customer to pay for product only when the customer uses it. The customer must provide the supplier with up-to-date (e.g., daily) information on stock level, and perhaps even forecasts of future usage. See also CPFR, and continuous replenishment.

**VPN (Virtual Private Network):** An arrangement among two or more organizations whereby a public network, such as the internet, is made to appear as a private, secure communications network to the participating parties.

**Wardrop's Principle:** A traffic equilibrium rule. Suppose commuters wish to travel from  $A$  to  $B$ . According to Wardrop's principle, at a user equilibrium where users choose the paths, among all paths along which there is a positive  $A$ -to- $B$  traffic, the travel time from  $A$  to  $B$  will be the same, whereas the travel time from  $A$ -to- $B$  is at least as great along paths not carrying any  $A$ -to- $B$  traffic. See also: Nash Equilibrium and Braess's paradox.

**Warehouse:** A DC in which product may be carried for an extended period of time, such as product that either has seasonal production or seasonal demand. Some warehouses may be specifically designed to handle refrigerated goods, high value/security goods, flammable goods, or other hazardous materials.

**Warsaw convention:** An international treaty ratified by most countries between 1929 and 1934 that sets standards for air carrier liability. For example, it sets standards for the minimum \$/lb that an air carrier is liable for loss of goods, as well as the length of time a shipper has to submit a claim for damaged goods.

**Wave:** In some warehouses, picking is done in batches called waves. A major motivation for waves is to gain economies of scale in picking. E.g., if only a few items are picked at a time, then manual pickers must do a lot of walking between picks of individual items. After one wave, one set of trucks are typically loaded.

**WBS (Work Breakdown Structure):** In project management, a hierarchal or tree-structured arrangement of the work to be done. At the highest level is the final deliverable. It is broken down into or described in terms of its components. These in turn or broken down, etc. Management of activities is frequently assigned in terms of the WBS, so being able to view the status of a project according to its WBS may be convenient for the individual manager.

**WERC:** Warehousing Education and Research Council. See <http://www.werc.org>.

**Winner's curse:** In auctions, the observation that the winner of an auction has a higher than average probability of having made an (optimistic)error in preparing his bid.

**WIP (Work in Process):** Inventory of partially completed product.

**WMS (Warehouse Management System):** A mainly software system for keeping track where product is stored in a warehouse, generating pick lists, and in general causing the proper outbound shipments to be constructed.

**WTO (World Trade Organization)**

**X12:** A standard for electronic communication of business forms. For example, form 810 is an invoice, and 856 is a shipping notice. See also: DISA.

**XML** (eXtensible Markup Language): An “open”, ISO standard data language, similar to, but more powerful than HTML. It is not only for storing and transmitting data, but also describing what the data mean. It is becoming a popular format for business-to-business transactions on the Web. Two features of it are that, like HTML, it uses tags, and an XML file is tree structured, as illustrated by the following example:

```
<line item>
  <sku> b40104 </sku>
  <quantity> 2 </quantity>
  <price>
    <currency> euro </currency>
    <value> 5.50 </value>
  </price>
</line item>
```

See <http://www.w3.org/XML/>.

**Yield management:** term used in the airline industry for revenue management.

**Zero sum game:** A situation in which the total amount of profit ( or “pie”) is fixed. Individual players by their actions can only affect how the profit is allocated (or pie is cut). Also called a constant sum game. In contrast, see Prisoner’s dilemma.

**Zone skipping:** A shipping method by which the shipper uses a public delivery service such as UPS or USPS to deliver its product the last few kilometers to the final customer, but the shipper uses its own trucks to ship its product for the initial long distance, skipping zones as perhaps defined by the public carrier’s rate schedule. The shipper delivers the product to a UPS or USPS office in the distant city for the final delivery. Zone skipping may be efficient because it avoids the initial sorting step incurred if the shipment is delivered to the public carrier at the origin city. Even though the shipper knows that this big collection of packages goes to one distant city, the public carrier rediscovers this as it is processed through its sorting system.