Supply Chain and Operations Management Glossary

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

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

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.

463 Pallet: A standard pallet for carrying cargo in the U.S. military. It is 88 inches by
108 inches and about 2 inches thick. It has 6 tie-down rings on the long side and 5
tie-down rings on the short side, Cargo on the pallet is held in place by nets. The
pallets are held in place on a cargo aircraft by a set of side rails. See also ULD.

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. 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.
Sometimes also called transactions-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.

Acceptance sampling: See AQL.

ACH(Automated Clearing House): A nationwide electronic payments system in the U.S.
that is popular for making electronic payments, bank to bank, business to
business, and business to government. See http://www.nacha.org.

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.

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

Act of God: In a contract, say for a delivery of goods, an event that is difficult to predict, prevent, and of low probability, e.g., tornado, hurricane, which if occurs, absolves one of the parties of the contract from having to satisfy the conditions of the contract, e.g., deliver the goods on time. Sometimes also known as a Force Majeure. Other events sometimes listed as Force Majeure are strikes, riots, explosions, and governmental actions.

ADC(Automatic Data Capture): Any method, such as bar codes and RFID for automatically entering data into an information system with minimal manual effort.

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)

AIDC(Automatic Identification and Data Capture/Collection): Methodologies, including bar codes, OCR, MICR, RFID, magnetic stripe, biometrics, etc. for identifying packages, documents, and people.

American option: See Call option, Put option.

andon: A Japanese term meaning literally a lantern, perhaps for signaling. In manufacturing it typically is a lamp displaying one of three colors: Green = operating normally, Yellow = help is needed, e.g., send a maintenance or changeover crew, and Red = production has stopped because of some problem. See also poka yoke, jidoka.

ANSI(American National Standards Insitute): see http://www.ansi.org or http://www.nssn.org 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.

APICS(American Production and Inventory Control Society): Also known as the Association for Operations Management. See http://www.apics.org. From 1980 to 2000 this organization popularized the use of MRP. APICS offers two certification exams: the CPIM and the CIRM.

Apollo: Planogram software from IRI.

AQL(Acceptable Quality Level): When a shipment of units of some SKU arrive, you may wish to inspect the shipment and reject it if "too many" of the units are defective. How is "too many" determined? A well defined way is to choose four quantities: 1) a high quality level known as the AQL, e.g., 0.5 % defective or less, 2) a low quality level, the Lot Tolerance Percent Defective(LTPD), e.g. 2% defective or more, 3) a producer's risk, α, e.g., .15, and 4) a consumer's risk, β, e.g., 0.1. We then want to choose an inspection plan so that the probability of rejecting a "good" lot having AQL% defective is α, and the probability of accepting a "bad" lot with LTPD defective is β. For example, if a single sample plan is used, then using the binomial distribution, and the above example numbers, it can be shown that one should take a sample of size 265 and accept if the number defective is 2 or less.

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.

Arbitrage: In its simplest form: buying a commodity at one price in one market and then immediately selling the same or equivalent commodity at a higher price in another market. More generally, if the commodity is a physical commodity such as corn or oil, then we say an arbitrage opportunity exists if the price for the commodity in market B is higher than the price in market A plus the transportation cost from A to B. In currency exchange markets an arbitrage opportunity exists if there are three markets, say euros, dollars, and yen so that you can exchange one euro for the equivalent in dollars, exchange those dollars for the equivalent in yen, and then exchange those yen for the equivalent in euros, and then find yourself with more than one euro.

ARIMA forecasting model: A class of forecasting models in which there may be three kinds of features: 1) Auto-Regressive(AR) terms to represent business cycle behavior such as tends to occur when demand is generated by equipment that needs to be regularly replaced as it wears out, 2) a Trend, or Integration(I) or differencing feature to represent demand that is steadily increasing, and 3) Moving Average(MA) terms which can capture the effect of a spike in demand, say, after our product was the subject of a favorable news story. These three features, AR, I, and MA, together are called ARIMA. A forecasting model with p AR terms, d differencings, and q MA terms, is said to be an ARIMA(p,d, q) model. Exponential smoothing can be shown to be an ARIMA(0, 1, 1) model. Early work on this class of forecasting methods was done by Box and Jenkins, so ARIMA models are sometimes called Box-Jenkins models.

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.

Assortment planning: Deciding how much to carry of which products. An important consideration is the substitution behavior of various customer types, that is, what product of yours or your competitors the customer will buy if you do not have her first choice in stock. See also Consumer choice, Multinomial logit.

ASTM: Originally the American Society for Testing and Materials, but now officially known as ASTM International, see http://www.astm.org . ASTM initially set standards for steel products around the 1900. If you were ordering steel rail from a mill you might specify that the steel have a certain hardness as specified by a precisely described ASTM test. ASTM then introduced standards for the cement industry. It now publishes standards and standard tests for a wide range of materials, such as testing the viscosity of lubricating oil, or testing the strength of plastic. Thus, a reasonable way of communicating a quality requirement between a manufacturer and a customer is via an ASTM standard.

ATO(Assemble to Order): Components are kept in inventory, however, a final product is assembled from these components only when a customer places an order for a particular product configuration. The ATO approach may be appropriate when there are a modest number of components, but a large number of different configurations into which these components could be combined to produce a product useful to some customer. Sometimes also called Build to Order.

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. Some sophisticated ERP systems allow the user to attach a probability to each promise or claim on inventory to account for expected cancellations of orders.

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, e.g., 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, e.g., on the basis of quality, price, delivery time, to supply this SKU.

Avoirdupois weight: A system of weights widely used in the U.S. and to some extent in the United Kingdom, Australia, and Canada. The central unit is the pound (lb). A pound is 0.45359237 kilograms. Other units of the Avoirdupois system are: grain = 1/7000 lb, dram = 1/256 lb, ounce = 1/16 lb, hundredweight (cwt) = 100 lb and "short" ton = 2000 lb. Beware that an Avoirdupois ounce is not the same as a Troy ounce and an Avoirdupois pound is not the same as a Troy pound. See also SI units, Troy weight.

B2B: Business To Business. Transaction between two businesses.

B2C: Business To Consumer. 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.

Backorder: unsatisfied product demand for which customer is willing to wait for shipment later, rather than cancel the order. See also: stockout. A backorder may cause accounting complications because a vendor typically cannot charge for a product that has not been shipped, in particular if payment is made by credit card.

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.

Barrel: Standard unit by which crude oil is measured, equals 42 US gallons.

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.

Bass model: A mathematical model of the sales over time of a product just after its introduction. Define: $S(t)$ = market size in period t, M = market size at saturation or maturity, p = innovator coefficient, $0 < p < 1$, q = imitators coefficient (could be negative). The Bass model says or predicts:
$$S(t+1) = S(t) + (p + qS(t)/M)*(M - S(t)).$$
The term $(M - S(t))$ represents potential customers who have not yet bought the product. The term $p*(M-S(t))$ represents new customers who will try the product just because they like to try new products. The term $qS(t)/M)*(M - S(t))$ represents new customers who will buy the product because they interacted with someone who has already bought the product.   A heavily advertised product will have a large p. A product that gains market because of good "word-of-mouth" will have a large q. Once you have three data points for a new product then you can estimate p, q, and M and estimate future sales. The plot of $S(t)$ as a function of t will give an S shaped curve, i.e., starting slowly at 0 corresponding to the p term, then getting steeper as a result of the q term, and then leveling off at M. See also: logistics curve, per cent done rule.

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, starts high because new equipment may have "birth defects", decreases to a low fairly constant rate for a long period of time, and then starts to 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.

Bi-matrix game: A two person game or competition in which one player's (or participant or firm) loss is not necessarily the other player's gain. The possible decisions and outcomes are described by two matrices. Consider two competing firms that must each choose an advertising level:

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                         Firm A decisions and  \profits
                  Advertise high |  Advertise medium | Advertise zero
                                 |                   |
  Firm B      Advertise    \ 5   |        \ 3        |       \ 4
  decisions   zero       -1 \    |      2 \          |     4 \
  and         -----------------------------|-------------------|--------------
  profits\    Advertise    \ 2   |        \ 1        |       \ 0
              high        0 \    |      1 \          |     5 \
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For example, if Firm A decides to advertise medium and Firm B decides to advertise zero, then Firm A has a profit of 3 while Firm B has a profit of 2. This is not a stable position, however, because if Firm A expects Firm B to Advertise zero, then it is better for Firm A to Advertise high and get a profit of 5. Now if Firm B expects Firm A to Advertise high, it is better for Firm B to Advertise high and at least have a profit of 0 rather than a loss of 1. This choice pair, "Advertise high" for both is stable, a so-called Nash equilibrium. Neither player can do better by changing unilaterally. It is not a Pareto optimum, however, because if both did "Advertise zero", they would each make a profit of 4 and thus both would be better off. The choice pair of both "Advertise zero", however is not stable. Each player is tempted to improve his lot a little by switching to "Advertise high. This is an illustration of the Prisoner's dilemma. See also, non-constant-sum game.

Billing weight pricing: see Dimensional weight pricing.

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 $n*p$, as n gets large and $n*p$ remains fixed. The binomial converges to the Normal distribution if p remains fixed, e.g. close to .5 and n gets large.

Blanket purchase order: An agreement between a buyer and a vendor that is intended to simplify the purchasing of repetitively purchased items. A blanket purchase order typically includes: a) period of time covered by the agreement, b) minimum dollar amount to be purchased over this time, c) maximum amount to be purchased over this time, d) list of SKU's covered, e) price for each SKU, f) delivery method and speed, g) who in buyer's organization is allowed to order under the agreement. If the minimum amount promised to buy is large, the vendor may give a price discount.

Blocking: In rail shipping, the process of deciding which cars are grouped together or connected in a block or train at a classification yard. As a car moves from origin to destination it may pass through one or more classification yards. At each yard it may be assigned to a new block. For speedy movement one would like to have all the cars with the same origin and destination to move as a single train from origin to destination. This would, however, require too many trains or blocks. To minimize handling, one would like to have as few blocks as possible that move across the country. Similar problems arise in the postal delivery industry, where one must decide how items get aggregated into bags/blocks at the beginning of a shipment, how these bags are moved across the country, and then how these bags are disaggregated back to individual items to get delivered to their destination.

BOL(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. A copy of the BOL is the shipper's receipt from the carrier. Once the recipient signs the bill of lading, it is legal proof of delivery by the carrier.

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 inventory: An arrangement by which a supplier holds specified amount of inventory for a downstream customer. The inventory is segregated either physically or electronically so that the customer is guaranteed that the agreed upon inventory is available. This arrangement is attractive for a retailer who does not have storage space but wants the assurance of having sufficient inventory. In a sense, this is the reverse of consignment inventory.

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. Typically forty to fifty feet long. In contrast, see flat, hopper and tank car.

Box-Jenkins forecasting model: See ARIMA.

BPI(Business Process Improvement): A method for improving an organization, typically by starting with what are the objectives of a particular operation, e.g., accounts receivable, and then working backwards to decide what steps are truly needed to achieve the desired objectives.

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. E.g., 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 better, with some of them experiencing increased travel time. The weak form is only that total travel time is increased. 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.

BTO(Build to Order): See ATO.

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. Some nice features of this style of work assignment are: a) it requires minimal supervision, b) it adjusts automatically according to how many workers show up for work on a given day, c) if workers are sequenced so that the faster workers are towards the output end of the line, then automatically all workers remain busy as long as there is work to do.

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.

CAFE(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. For an inbound call center a major task is predicting how many of each type of call will occur in each 15 minute interval of the day and then having enough people with appropriate skills to meet this call demand. For an outbound call center a major task is deciding when is the best time of the day to call each number that is on the call list. See also: predictive dialing.

Call option: An contract between two parties A and B that gives A the right, but not an obligation, to buy from B a specified quantity of some commodity at a specified price by some future date. It is a European option if the right to buy is for a specific date. It is an American option if the right to buy exists for any day up to the expiration date of the contract. See also Put option.

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.

CAM(Common Area Maintenance): An additional fee that retailer in shopping center, or renter in general , may be required to pay a landlord in addition to the base rent. The CAM fee may cover things such as taxes and insurance that the landlord must pay. The CAM fee serves two purposes for the landlord: 1) It allows the landlord to quickly pass on the risk to his tenants of unpredictable cost increases faced by the landlord, and, 2) it allows the landlord to quote a rent that may appear low to a prospective tenant who does not pay attention to the existence of CAM fees. Standard responses for a tenant include: a) request a clause that allows the tenant to terminate the lease at no penalty if the increase in the CAM fee per year exceeds some specified per cent, and b) require a clear definition of expenses that may be included in the CAM fee. E.g., capital improvements may not be included in the CAM fee.

Cannibalization: The loss of sales of an existing product of ours to a new product that we introduce. We do not want to introduce a new product if it will cannibalize "too much" of the sales of the existing product. Let P_x = the profit contribution per unit of the existing product, P_n = the profit contribution per unit of the new product, V_x = unit sales volume of the existing product prior to introduction of the new product, V_n = unit sales volume of the new product(an estimate), V_K = cannibalized sales, i.e., sales of the existing product lost to the new product, and V_M = total size of the market. Our increase in profit from introducing the new product is $P_n V_n - P_x V_K$. Thus, total profits will increase if $(P_n /P_x) > (V_K/V_n)$, i.e., the ratio of profit contribution of new to old is greater than the fraction of the sales of the new product that are due to cannibalization. How might we estimate the cannibalization ratio (V_K/V_n)? A simple model is to assume that all product users, of ours and our competitor's products, are equally likely to switch to the new product. In that case, (V_K/V_n) is equal to the market share, V_x /V_M, of the existing product. If the new product does not increase the market size, then it is also clear that there must be some cannibalization if the unit sales of the new product exceeds the unit sales we currently are not getting, i.e., we must have $V_K \geq V_n - (V_M - V_x) = V_n + V_x - V_M$.

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. E.g., a shipper has at least nine months to file a claim for damage by the carrier, and at least two years to file a lawsuit if the carrier disallows the 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.

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: Firm that carries a shipment of goods, as opposed to the shipper, who is the firm who sent or originated the goods.

Carrying cost: The cost of owning something, typically inventory, typically stated as a per year rate. The major components of inventory carrying cost are: interest or cost of capital tied up in the product; explicit storage related costs such as warehouse costs, e.g. refrigeration costs for frozen goods, insurance, taxes,; implicit or opportunity storage costs because carrying more of one product in a finite capacity warehouse forces us to carry less and give poorer service for some other product; inventory risk costs such as shrinkage(theft, damage, etc.), and obsolescence.

Cartage: Local hauling, e.g., within a metropolitan area.

Case: standard shipping unit to retailers, e.g., supermarket goods are typically shipped in units of a case, e.g., 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.

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

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 that 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.

CFAR(Collaborative Forecasting and Replenishment): See CPFR.

CFO(Chief Financial Officer): Manager responsible for financial planning of the organization. Typically also responsible for record-keeping and computer information systems.

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.

CIO(Chief Information Officer): Manager typically responsible for computers and information systems. May report to a CFO.

CIRM(Certificate in Integrated Resource Management): Offered by APICS.

Clarke Wright savings heuristic: In LTL routing, a method for assigning customers to loads. It starts by(conceptually) making a separate trip to each customer. Then at each iteration it combines those two trips A and B for which net savings is greatest. For example if we combine trips A and B, we save the distance back to the depot from the last stop on A plus the distance from the depot to the first stop on B, but incur the additional distance from the last stop on A to the first stop on B. Trips A and B are

not combined if the total load would exceed truck capacity. Iterations continue as long as net savings are positive or total number of trips still exceeds trucks available.

Classification yard: Also known as a marshalling yard, or perhaps a hump yard. A facility at a rail hub for disassembling incoming trains and reassembling them for movement out of the hub. Loosely speaking, a classification yard is the railroad analog of a what a DC is for trucks. In the simplest design there is a single incoming track which branches into typically from 20 to 80 parallel tracks. Each of these tracks is long enough to assemble an entire outgoing train. At the outgoing end these assembly tracks merge into a single outgoing track where completed trains depart. A common design is to have a hill or "hump" at the entrance to the yard. Once an individual rail car is pushed over this hump, gravity will propel the car forward. A towerman will direct a car to its appropriate track to join its outgoing train. The towerman can use retarders or track brakes to slow down a railcar before it connects to its outgoing train. See also blocking.

CLM(Council of Logistics Management): Not-for-profit organization for professionals interested in logistics management. See http://www.clm1.org. In 2005 it changed its name to Council of Supply Chain Management Professionals(CSCMP). See: www.cscmp.org .

CMYK color: A color system based on the three colors, Cyan, Magenta, Yellow, and the "Key" color, black. This system is typically used in color printers. The system is subtractive in that if you print all three of C,M,Y, you get black. See also, Pantone, RGB, HTML, and NCS color.

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: Sometimes abbreviated as CV, and defined as the standard deviation divided by the mean. For two locations or two SKUs with dramatically different mean sales, the CV is one way of measuring relative variability in sales.

The CV makes sense only for positive random variables, otherwise the mean could be 0. The exponential distribution has a CV = 1, so a CV of 1 is a natural borderline for classifying a random variable as highly random or not so random.

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. COGS is understood to include only variable costs but not fixed costs.

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. In a transportation auction, a carrier might want several lanes that share a common end point, so the carrier might submit a bid saying he wants lane X only if he also gets lane Y.

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 θ = mean number of orders received in a period and the number of units requested in each order has mean μ and standard deviation σ, then the number of units requested per period has mean $\theta\mu$ and variance $\theta(\mu^2 + \sigma^2)$. If f_j is the fraction of the orders that are of size j, for $j = 1, 2,\ldots,$ and P_n is the probability of total demand in units being equal to n in a period, then:

$$P_0 = e^{-\theta},$$
$$P_1 = \theta * f_1 * P_0 ,$$
$$P_2 = \theta * [f_1 * P_1 + 2 * f_2 * P_0]/2 ,$$
$$\ldots$$
$$P_j = \theta * [f_1 * P_{j-1} + 2 * f_2 * P_{j-2} + 3 * f_3 * P_{j-3} + \ldots + j * f_j * P_0]/ j .$$

The most common choice for the batch size distribution is the logarithmic distribution, in which case the distribution of total amount ordered in a period has the negative binomial distribution.

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.

Consignment: A selling method in which control, but not ownership, of a product is turned over to a retailer. The supplier or manufacturer does not get paid until the retailer sells the product, at which point the retailer receives a commission. This arrangement may be useful when it is easy to verify the selling price and the retailer has modest financial resources relative to the supplier. See also: rack jobber.

Consist: In U.S. and U.K. rail systems, the set of vehicles, engines included, that make up a single train.

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

Constant sum game: See Zero sum game.

Consumer choice model: A model for predicting how much we will sell of various products based on customer preferences and which products are available. A simple version is to partition the market into segments, estimate the size of each segment, and for each segment and product, estimate a reservation price. The model then assumes that each segment will buy that one product which a) is in stock, and b) has the greatest consumer surplus for that segment, that is, (reservation price – market price) is greatest. Another model for how consumers choose among products is the Multinomial logit model. A third model used by some auto manufacturers and some airlines is the substitution matrix approach, whereby one estimates a matrix of parameters t_{ij} = fraction of customers who were ready to buy product i, then switch to trying to buy product j when they find that i is not available.
See also assortment planning, logit model, multinomial logit.

Consumer risk: Probability a low quality lot is accepted. See AQL.

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.

Container: A box, typically of steel, but sometimes aluminum, that is packed with goods and can be carried on a containership for shipment over the ocean, or carried on a railcar for movement over long distances over land, or carried on a truck trailer for pickup of goods from the original manufacturer or for delivery to the final customer. The attraction is that there need be no manual handling of the goods once the goods are placed in the container at the originator until the goods are received by the customer. For international shipping, some common ISO standard sizes are
a) 20 feet long, about 8 feet wide, and about 8.5 feet high(a so-called 1 TEU),
b) 40 feet long, about 8 feet wide, and about 8.5 feet high, c) 40 feet long, about 8 feet wide, and about 9.5 feet high, d) 45 feet long, about 8 feet wide, and about 9.5 feet high, e) 48 feet long, about 8 feet wide, and about 9.5 feet high. In the U.S., another popular size is 53 feet long, about 8.5 feet wide, and about 9.5 feet high

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 cost sharing, the retailer will typically advertise too little with regard to maximizing the total profits of supplier plus retailer. Define:
p_r = retail price per unit received by retailer, p_w = wholesale price per unit paid by retailer to supplier, c_r = processing cost per unit incurred by retailer, c_w = processing cost per unit incurred by supplier, c_a = advertising cost required to generate one more unit of sales, and f = fraction of advertising cost paid by retailer. We would expect c_a to increase as we advertise more. At the advertising level that maximizes total profits we should have that have that the marginal cost of generating the additional unit of sales = the marginal profit, i.e., $c_a = p_r - p_w - c_r + p_w - c_w$. If the retailer is choosing the advertising level, we would like his marginal advertising cost at this level of advertising to equal his marginal profit, i.e., $f*c_a = p_r - p_w - c_r$. Solving, $f = (p_r - p_w - c_r)/(p_r - c_r - c_w)$, i.e., the retailer should pay a fraction of the advertising equal to her fraction of the total profit per unit at the margin. In practice, the supplier does not know c_r (and perhaps not even c_w). Also, the supplier must worry about the possibility that the retailer is getting a secret rebate from the advertising agency, so

the supplier will probably want to use the *f* from the formula above as a lower bound on the fraction of advertising cost paid by the retailer. Because of such issues, in practice, the supplier will typically also set an upper bound on how much co-op advertising the supplier will pay as a fraction of total sales by the retailer. See also incentive compatibility.

Cord: Standard unit of measurement for buying and selling raw wood, equal to 128 cubic feet when the wood pieces are "ranked and well stowed". Typically, the wood is packed into a 4' by 4' by 8' stack. "Ranked" means the long dimensions of the pieces are parallel, "Well stowed" means packed as tightly as possible.

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. E.g., 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:

$CA \le 88$; $CB \le 91$; $CC \le 90$; (Else the player is better off by himself);
$CA + CB \le 150$; $CA + CC \le 148$; $CB + CC \le 151$;
          (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 a 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, Nucleolus, Shapley value.

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

Cost of capital: An interest rate used in selecting projects to undertake, usually by means of a net present value analysis. The cost of capital is usually at least equal to the interest rate that must be paid for borrowing money. It may be chosen to be somewhat higher to take into account the riskiness of projects. See also, ROI.

Countertrade: A form of international barter wherein the two parties exchange goods rather than goods and money. Useful when either or both of the parties is in a less well developed country which does not have a lot of hard currency reserves or marketing ability in the other country.

Cournot game: A situation where there are two suppliers, each producing the same commodity product, each choosing a quantity to produce without sharing information, and the single market price is a function of only the amount produced in total by the two firms. A good example is the situation faced by crude oil producing nations. If all suppliers optimize individually, they typically make less profit than if they cooperate, either implicitly or explicitly, and restrict production to less than their individual optimum. See also prisoner's dilemma and non-constant-sum game.

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 *xbar* and *ybar*, then the covariance of this sample is defined as: $\Sigma_i(x_i - xbar)*(y_i - ybar)/n$. 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. See also, correlation.

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.

CPIM(Certificate in Production and Inventory Management): Offered by APICS.

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. 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, TAPI.

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.

CSCMP(Council of Supply Chain Management Professionals(CSCMP). Known as the Council of Logistics Management prior to 2005. See: www.cscmp.org.

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

Cubing: the process of measuring the height, width, depth and weight of each package, and then based on this information, deciding either where to store the package in a warehouse or how to pack the package on a pallet or vehicle for shipping. Automated machines are available for much of this process.

cwt.: hundred weight, one hundred pounds. For many products, e.g., raw milk, some steel products, the standard unit of measure in the U.S. is the cwt.

Cycle Counting: A form of checking physical inventory by which each day, the physical inventory of just a few SKU's is checked. On succeeding days, one cycles through the remaining SKU's so that in a finite period of time, say a year, one has cycled through the entire product line. This is in contrast to the once-a-year complete physical inventory check that is done by some firms. The main advantages of cycle counting is that the workload is smoother throughout the year, and more important SKU's may be checked more frequently than less important ones. The reason for doing any kind of inventory checking is that with high probability, "unofficial transactions", e.g., petty theft, will occur so the "perpetual" inventory records in the computer will not agree with the physical inventory out on the floor. For financial reporting reasons, one may prefer a single comprehensive physical inventory

performed over a weekend. Thus, a financial document can make a precise claim regarding inventory on a particular day.

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, QR code, and MaxiCode. For more details see www.aimglobal.org.

DC(Distribution Center): A facility that accepts inbound shipments, breaks them up and recombines them differently into outbound shipments. E.g., it may accept a shipment of baby food from Gerber and a shipment 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. A modest-sized DC may have about 10,000 square meters of floor space. A large DC may have over 100,000 square meters of floor space. It may have from a half dozen to 100 dock doors for receiving and sending material. Summarizing, the major activities in a DC are receiving from inbound vehicles, put away into storage, picking in preparation for shipping, sortation according to outgoing load, and loading the outbound vehicle.

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 are 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.

Demand planning: Demand forecasting in which the effect of proposed price changes, advertising and other promotions are taken into account. One of the goals of demand planning is to better coordinate demand with production capacities.

Demographics: The features of people in a market segment that play a big role in determining their interest in your product. These features typically include: age, income level, educational level, gender, location, ethnicity, marital status, occupation, home ownership, religion, etc.

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.

Depot: A distribution center(DC). In industry it usually means a DC that does not carry inventory. In the military the term may mean a DC that carries inventory.

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.

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.

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

DIN(Deutsches Institut fur Normung): A nongovernmental German standards system. It includes standards for electronics, telecommunications, vehicle engineering, packaging, fasteners, photography, and more. Similar to ANSI and ISO. See www.din.de

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: 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, gray market, 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; Curtains that surround the truck door to provide protection from the weather for personnel loading or unloading the truck. A dock door that is used mainly for unloading is sometimes called a strip door. Some warehouse managers in the U.S. try to arrange truck traffic to be counterclockwise around a warehouse. Thus, when a driver is backing into a dock door the driver is not backing in from the blind side.

Dogtrack: In a DC sortation system, a recirculating conveyer on which items to be sorted according to destination are placed. See also sortation, wave.

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 decisionmakers, 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., a local trucking firm may pickup material and deliver it to an intercity depot. At the destination city, another local trucking firm may pickup the material at the destination intercity depot and deliver to the final destination. Originally, in the 1800's, a dray was a cart, wagon, or sled without sides for doing local hauling.

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.

Due Diligence: When parties A and B are contemplating the making of an agreement, due diligence by A is the process of verifying as fact the various claims, both explicit and implied, made by B. "Diligence" here means to do the hard work. "Due" here means what is normally expected as part of properly concluding an agreement.

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. In some finance literature the term Dutch auction is (mis?)used to mean a multi-unit auction in which single common price applies to all winners.

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 by the government to a firm when the firm 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. See also FTZ.

e: The mathematical constant 2.71828182846 useful in computing continuous compounding of interest. e = limit as n goes to infinity of $(1 + 1/n)^n$.
For example, if continuous compounding is used at interest rate r (stated as a fraction) 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. A final end customer typically orders a single unit. A retail store may order material from a

warehouse in cases, where a case typically contains from a half dozen to two dozen single units. Also see piece-pick.

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 the 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. The following illustrates the differences for a manufacturer to distributor to retailer system:

	Manufacturer	Distributor	Retailer
Physical inventory:	5	11	8
Echelon inventory:	24	19	8
Pipeline inventory:	5	16	24

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: With regard to a supply or demand curve:
(% change in quantity demanded)/(% change in price). If the elasticity = 1 for a supply curve, it means that a 1% increase in price will cause a 1% increase in quantity supplied. If the elasticity of a demand curve is -1 (sometimes called unit elasticity) then a 1% increase in price will cause a 1% decrease in demand. A supply curve has unit elasticity if it is of the form $Q = b*P$, for some positive parameter b. A demand curve has unit elasticity if $Q = k/P$, for some positive parameter k. A supply or demand curve is said to be inelastic if quantity is not very sensitive to price, e.g., an increase in price causes very little increase in supply or very little decrease in demand.

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(about 28 decimal digits)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 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), Customer Relationship Management(CRM), Sales, Order management, and Distribution .

Escrow: Given that parties A and B want to do business together, an escrow is the placement or deposit of funds or some object by party B with a reputable third party, e.g. a bank trusted by both A and B, with the agreement that the funds or object on deposit will be made available to A when certain conditions are satisfied, e.g., presentation of official documents that goods have been shipped, or a sales closing

agreement has been signed, or that B has gone bankrupt, or B has defaulted on some agreement. See also Letter of credit.

Estoppel principle: Given an agreement between party *A* and party *B*, estoppel is a legal principle that in certain situations allows party *A* to violate part *X* of an agreement if an action of party *B* reasonably might lead party *A* to believe that part *X* did not apply. For example, if a carrier *B* repeatedly assures the shipper *A* that his shipment was safely delivered, but only much later shipper *A* learns that his shipment was lost or damaged, then *A* might be relieved of the nine month limitation of the Carmack amendment for filing a damage claim.

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

Exponential distribution: If λ 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 $\lambda * e^{-\lambda t}$, and the c.d.f. is $1 - e^{-\lambda t}$. 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*, B_t is the forecast computed after observing D_t and *alpha* is the smoothing constant, e.g., 0.2, then
$B_t = alpha * D_t + (1-alpha) * B_{t-1}$. It is a special case of the ARIMA class of forecasting models, specifically, it is an ARIMA(0, 1, 1) model. There are extensions to include trend, seasonality, and estimation of demand variability. See also Croston's method and Winter's method.

Exposures: In marketing, the number of times that prospective customers hear or see an advertisement or message. E.g., if a magazine A has a readership of 1000 and magazine B has a readership of 1500 and a certain ad is run twice in each magazine, then the number of exposures is 2*(1000 + 1500) = 5000. Contrast this with "Reach", which is the number of people who see the message at least once. If there are 500 readers who read both A and B, then the exposure of this ad campaign is 1000 + 1500 − 500 = 2000. Exposures are also sometimes called impressions.

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.

Facings: The number of copies of an SKU that are visible to a picker in a warehouse or to a potential customer in a store. If a particular SKU can be stored at most 5 deep on a shelf and you want to carry 6 units, then at least 2 facings will need to be allocated to this SKU. In a store, an additional consideration is that increasing the number of

facings may increase the sales. See slotting, Planogram.

Factoring: Selling your accounts receivable at a discount. It is almost the same as borrowing with your accounts receivable as the collateral.

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: 203-847-700. These standards are officially recognized by the SEC and the AICPA.

Favored Nation: A clause in a contract between a Vendor V and a buyer B that says that if V ever supplies essentially the same product to some third party at a price lower than that charged B, then V will provide it to B at this same lower price.

FBO(Fixed Base Operator): A service station for aircraft at an airport. If your corporate aircraft lands at a distant airport, the FBO at that airport can provide fuel, parking, hangar space, maintenance, and various other ground services.

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.

FICO score: A scoring formula developed by **F**air **I**saac **Co**rporation to estimate the credit worthiness of a prospective customer. The score can range from 300 to 850, with a score above 720 consider good and less than 610 poor. The main component of the formula is how quickly the customer has paid bills historically. The formula cannot take into account ethnicity, religion, sex, and marital status. Historically, a score for a prospective customer, based on this formula has been available to a business for a nominal fee, of say $15, from any of the three major credit reporting companies, Equifax, Experian, and TransUnion.

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.

FOA(Final Offer Arbitration): A method for reaching agreement between two parties whereby each party makes a final offer and then an arbitrator(usually mutually agreed upon) chooses as binding the one offer of the two that the arbitrator judges to be most equitable. This method has been used in settling transportation disputes when transportation rates were more regulated. A shipper might think that his good falls in a certain category and should qualify for a certain low rate while the carrier feels that the good should be classified as a good with a higher charge. Each party is motivated to propose a somewhat reasonable price, otherwise, he increases the probability that his offer will be rejected and the other offer will be accepted. FOA is sometimes also known as Pendulum arbitration.

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.

Focus group: A method for assessing attractiveness of a product, or a proposed new product, or advertising for a product. A group of six to ten people is assembled in a focus group room, along with a moderator or facilitator. A major purpose of the group discussion is to identify issues not thought of by the product or advertising designers. The session may last for one or more hours and is usually video-taped for later study. The room may also have a one-way mirror so that product designers in an adjoining room may unobtrusively observe the discussion. The moderator will introduce the product and provide some guidance for the discussion. Another purpose of the moderator is to make sure that an uninformed dominant participant does not suppress the observations of well informed shy participants. When assembling a focus group, participants are selected based on their demographics so as to represent a cross section of the target market.

Force majeure: French for major force, or event beyond control. See Act of God.

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. Two general types are highlift, e.g., up to 12 meters, for placing or picking pallets in a warehouse storage, and low profile lift trucks for moving pallets off and on a truck. Forklifts for putting or picking in a warehouse, as opposed to loading or unloading a truck, may also be narrow so as to fit in narrow aisles, and they may have a swing mast fork that is able to rotate 90 degrees about a vertical axis so as to pick without requiring the vehicle to turn within the aisle. Another feature available is a "reach fork". It is able to extend and place or pick pallets that are stacked two or more deep in a rack. Other classifications for forklifts is whether or not they are explosion resistant or not. A fork lift is sometimes called a lift truck. Some forklifts have just three wheels. This gives greater maneuverability but at the expense of stability. Battery powered forklifts may be alternating current(AC) based or direct current(DC) based. The drawback of AC is higher initial expense, but the benefits of AC are:
a) lower maintenance, e.g., because the motor is completely enclosed,
b) greater efficiency, e.g., because the AC motor can recapture energy with regenerative braking, and c) better performance in terms of acceleration.

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.

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.

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.

FTP(File Transfer Protocol): A standard method for electronically moving files between business partners.

FTZ(Free trade zone): Typically a small region in a less developed country where a company may import materials and export product with minimal taxation, and use local labor.

Furlong: 1/8 mile.

GAAP(Generally Accepted Accounting Principles): A set of rules for preparing accounting statements in the U.S. See also: IFRS.

Galileo: A European GPS system.

Gambler's Ruin: A characterization of the fact that even if the odds are in our favor, we may still go broke with high probability in repeated encounters with 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 $q = 1-p$; our starting wealth is \$$w$ and our competitor's wealth is \$$u$, then 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.

Gamma distribution: A probability distribution with two parameters, k and λ. The mean is k/λ and the variance is k/λ^2. If k is an integer, then a Gamma random variable has the distribution of the sum of k independent exponential random variables, each with mean $1/\lambda$. For example, if demand occurs in a Poisson stream at rate λ, and we reorder in batches of size k, that is, place another order after every k demands, then the time between orders has a Gamma distribution. The probability density function is $f(x) = \lambda e^{-\lambda x}(\lambda x)^{k-1}/\Gamma(k)$, for $0 \leq x$.   Note, for k integer, $\Gamma(k) = 1*2*3\ldots*(k-1)$.

Gantt chart: A graphical device for displaying a schedule. Time is listed horizontally and the various resources or machines being scheduled are listed vertically on the left. For each resource, the activities that are assigned to it are listed horizontally in its line. The graph is attributed to Henry Laurence Gantt (1861-1919). Gantt was a colleague of Frederick Taylor at Midvale Steel Company.

GATT(General Agreement on Trade and Tariffs). See also, WTO.

Geometric distribution: A probability distribution that is sometimes used to model order size in a demand process. It has a single parameter $0 < p < 1$. Define $q = 1 - p$. The Prob{order size $=x$} $= q^x p$., for $x = 0, 1, 2,\ldots$ The mean is q/p and the variance is q/p^2.

GHz(Giga Hertz): Billion cycles per second.

Giffen good: A good for which demand increases if the price increases. Examples might be jewelry or potatoes. If the price of a piece of jewelry is increased, a wealthy potential buyer might interpret the price as indicative of quality and tend to buy the more expensive item. Potatoes are at the other extreme. An impoverished consumer with barely enough money for food, might, in addition to potatoes, buy some other, "luxury" foods if potatoes are cheap. If the consumer must pay more for potatoes, however, the consumer could afford less of the luxury food and thus increase the consumption of potatoes to meet nutritional requirements.

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.

Glonass: A Russian GPS system.

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. GPS, along with cell phone technology, allows a central office to have up-to-the-minute information of every vehicle in its fleet. See also Galileo and Glonass.

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 *LATi* is the latitude of point *i* <u>in radians</u>, and *LONGi* is the longitude of point *i* <u>in radians</u>, then the great circle distance in miles between cities *i* and *j* is 3959*acos(sin(*LATi*)*sin(*LATj*)+cos(*LATi*)*cos(*LATj*)*cos(ABS(*LONGi-LONGj*))). 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.

Greige goods: Typically pronounced "gray goods". Term used in fabric industry to mean a fabric that has not yet been dyed or bleached.

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. A multi-character code may be assigned to each part type, where the code is based on such things as the shape, e.g., round, square, etc.,

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

Hamiltonian Circuit: The traveling salesman problem (TSP). A path, e.g., in doing LTL deliveries, in which, given a set of cities, a vehicle visits each city exactly once and returns to the starting city. Also relevant to sequencing of tasks on a machine in which there are changeover times that depend upon the immediate predecessor and successor task. Usually the objective is to minimize the distance travelled.

Hamiltonian Path: Same as Hamiltonian Circuit, except that a starting city is specified and the vehicle need not return to the starting city.

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. Maritime transport of hazardous materials is regulated in part by IMDG.

HDPE(High Density PolyEthylene): Containers made from HDPE tend to be opaque and stiffer than containers made from other plastics. Non-food containers, such as for laundry supplies, tend to be made out of HDPE. Complex shape containers can be made by welding two shapes together. Because HDPE in its pure form consists of only carbon and hydrogen, it can be burned without producing notable toxic fumes. See also PET, PVC, and LDPE. An HDPE container is marked with a "2" recycling code near the bottom.

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

Heijunka: Japanese word for "make level and flat", demand leveling, or production smoothing. A manufacturing philosophy of producing a product and all its components at a constant rate to just meet average demand.

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

HID(High Intensity Discharge): A form of lighting popular in warehouses. Light is produced by an arc discharge in a metal vapor, e.g., sodium. HID is about 5 times as efficient as incandescent light. HID is able to operate in a wider range of temperatures than fluorescent lamps. An HID lamp requires from 30 to 300 seconds to start up cold, even longer if it has been recently shut off and then restarted.

Holding cost: See Carrying cost.

Holt-Winter's method: See Winter's method.

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.

HOS(Hours of Service) rules: For truck drivers in the U.S.A. starting in 2004, the basic rules from the Federal Motor Carrier Safety Administration are that before a driver starts a duty or service period, a) the driver must have been off-duty for at least 10 consecutive hours, b) the duty period can be at most 14 hours long, c) during the duty period there can be at most 11 hours of driving, d) during 7 consecutive days there can be at most 60 hours of on duty, and e) during 8 consecutive days there can be at most 70 hours on duty. From 1939 to 2004 the rules were: a) at least 8 hours off duty, b) the duty period can be at most 15 hours long, and c) at most 10 hours of driving during a duty period.

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.

HTML color: A system, based on the RGB system, for representing color in displays on the World Wide Web. See also, Pantone, CMYK, and NCS color system.

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 telecommuncation network this corresponds to a so-called ring network. See also DC.

Hump yard: See Classification yard.

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.

IBC (Intermediate Bulk Container): A container for transporting liquids. A typical capacity is 330 gallons, as compared to the common, traditional 55 gallon steel drum. The IBC can be made from a variety of materials, most typically plastic. It is typically configured with slots in its base so it is easily handled by a fork lift.

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.

IFRS (International Financial Reporting Standard): A set of principles for preparing financial statements, mainly the balance sheet and the income statement of a firm. IFRS is used by the European Union and a number of other countries. See the International Accounting Standards Board, http://www.iasb.org/ In contrast, for the U.S., see GAAP. One difference between GAAP and IFRS is that IFRS does not allow the LIFO method of inventory evaluation.

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.

IMDG (International Maritime Dangerous Goods code): A set of standards for the handling of hazardous materials in maritime shipping. See http://www.imo.org/

Impossibility Theorem: Given a vendor V, who has a product that prospective buyer B, is considering buying, the Impossibility Theorem says there is no well-defined procedure for getting V and B to agree upon a price such that the procedure: 1) motivates both V and B to be fully honest, e.g., have B reveal honestly how much he is willing to pay and have V reveal honestly how little he is willing to accept, 2) is efficient, e.g., will always cause a deal to be reached if the amount that B is truly willing to pay exceeds how little V is truly willing to accept, 3) involves no outside encouragement or coercion, e.g., by a government, to cause an agreement to be reached. There are various versions of this theorem for various market situations. One of the earliest is due to Arrow, K.(1950), "A Difficulty in the Concept of Social Welfare", *The Journal of Political Economy*, vol. 58, no. 4, pp. 328-346. See also

Vickrey auction and incentive compatible.

Impressions: See Exposures.

Inbound: A shipment into a DC. Tends to be on larger vehicles, e.g., rail.

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. In an auction, the term means that the auction structure motivates bidders to bid their true valuation for the object being sold. See also: co-op advertising, transfer price.

Incoterms: A set of definitions useful in specifying international shipping agreements, for specifying who bears what risk and responsibilities from when the goods leave the seller's dock until the goods are delivered to the buyer's dock.
See http://www.iccwbo.org/index_incoterms.asp

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

Internal Rate of Return: See IRR.

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(internet protocol) form of packet switched 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).

IP(Integer programming): a generalization of linear programming that allows some variables to be restricted to integer values, 0, 1, 2, …. It is very useful for planning models with go/no-go decision variables, e.g., build a warehouse or not.

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.

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.

IRR(Internal rate of return): An interest rate such that the cash flow streams of a project have a net present value of zero. The IRR should be used with care because it has two flaws: 1) a stream of cash flows with two or more changes in sign of the cash flows may have two or more distinct IRR's, so it is not clear which IRR to use, and 2) Even though project A may have a higher IRR than alternative project B, it may nevertheless be more profitable to undertake project B. As an illustration of (1) consider a project that requires an initial investment of $1M, after one year it pays back $2.5M, but requires a shut down payment of $1.55M at the end of two years. There are two internal rates of return that make the NPV of the above cash stream zero: 13.82% per year and 36.18%. If our cost of capital is 24% per year, is this project attractive? NPV analysis with a cost of capital of 24% will show that this project should be accepted. As an illustration of (2), suppose that project A requires an initial investment of $2M and then pays of $1.3M after one year and $1.3M after two years and then the project ends. An alternative is project B. It requires an initial investment of $4M and then pays off $2.5M after one year and $2.5M after two years and then the project ends. Which alternative, if any, should be accepted if our cost of capital is 12%? IRR analysis would say project A because its IRR is about 19.4%, whereas the IRR of B is about 16.3%. NPV analysis would choose project B because B's NPV is about $338,843, whereas the NPV of A is about $255,198. Project A is better because, even though its IRR is only 16.3%, it allows more money to be invested at this rate, money that would otherwise be invested at only 12%, or equivalently, borrowed at 12%.

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*d1 + 2*d2+…+9*d9) mod 11. A check digit of 10 is represented by X. The check digit will catch any single digit error or any single transposition error. 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 by ISO, 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. ISO 9000 has various components. For example ISO 9000-3 is concerned with software design and development. ISO 9003 is concerned with final inspection.

ISO 14000: a set of standards, originated by ISO, for environmental management.

Jake brake: A feature, developed by Jacobs Vehicle Systems, of some truck engines so that the engine, rather than the conventional brakes, can be used to slow down the

truck, thus saving 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. A Jake brake is attractive for vehicles that are driven in mountainous regions because it may save wear on the regular brakes.

jidoka: A Japanese term associated with the Toyota Production System developed by Taiichi Ohno. Effectively, jidoka means the use of a mechanism for stopping a production line immediately when the mechanism detects that there is a problem, such as the line is producing poor quality product. The jidoka philosophy is that the line will not be restarted until the cause of the poor quality is identified and fixed. A simple literal translation of jidoka from the Japanese is automation. See also Andon and Poka yoke.

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 term meaning improvement, more generally, continuous improvement. A client once asked an improvement consultant: "When will we complete this improvement project?" The consultant replied: "Never, if you do it right." See also Jidoka.

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.

kerf: width of material removed by a saw cut. In cutting stock problems, say when precisely cutting a long piece of wood into a set of smaller target lengths for door and window frames, one must take into account the kerf of the saw blade when deciding where to make the cuts so as to get the target lengths.

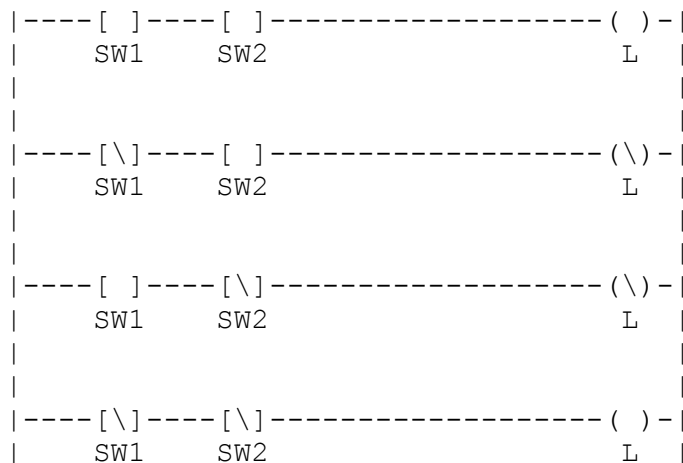**kilogram**: 1000 grams. 2.2046 pounds. See SI units.

kit: a collection of components placed together, perhaps in a container, that tend to be used together. E.g., 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: 6076.11549 feet/hour.

kPa(kilo-Pascals): Measure of pressure in the metric system. E.g., truck tire pressures outside the U.S. tend to be measured in kPa. The conversion to psi(pounds per square inch) is psi = .14504*kPa. One kPa is approximately equivalent to 10.2 grams/square centimeter. See also SI units.

KPI: Key Performance Indicator. See also Balanced scorecard.

Ladder logic: Notation widely used for programming of Programmable Logic Controllers(PLC). Many pieces of industrial equipment, such as conveyors, elevators, doors, lights, switches, etc., are controlled by PLC's. The notation originated from electrical diagrams that predate PLC's. The notation is called ladder logic because such a program resembles a ladder with rungs. Each rung of the ladder corresponds to a statement that is checked for truthness. Below is a ladder logic diagram that describes how a single light, L, can be turned on or off by either of two switches, SW1 or SW2.

```
|----[  ]----[  ]------------------ (  ) -|
|     SW1     SW2                    L    |
|                                         |
|                                         |
|----[\]----[  ]------------------ (\) -|
|     SW1     SW2                    L    |
|                                         |
|                                         |
|----[  ]----[\]------------------ (\) -|
|     SW1     SW2                    L    |
|                                         |
|                                         |
|----[\]----[\]------------------ (  ) -|
|     SW1     SW2                    L    |
```

A PLC will continuously loop through or execute the ladder diagram program that controls the PLC. The processing is down from top to bottom over the rungs and from left to right within a rung. So for example, the first rung above says that if both switches are TRUE, i.e., "On", then the Light should be On. The second rung says that if SW1 is off and SW2 is on, then the Light should be off. The third rung says that if SW1 is on and SW2 is off, then the Light should be off. The fourth rung says that if SW1 is off and SW2 is off, then the Light should be on.

Lanchester equations: a pair of differential equations that describe the losses incurred by two competitors or combat forces as a function of the amount of resources or size they bring to bear to a competition or battle. 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.

LDPE(Low Density PolyEthylene): A soft plastic often used as a wrapping material. Tends to be opaque. Objects made from LDPE are typically marked with a "4" recyling code.   Because pure LDPE is composed of only the elements carbon and hydrogen, it can be burned without producing toxic products. See also: PET, HDPE, and PVC.

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

Lean production: Just as a lean person has a small waist, lean production has minimal waste(see Muda). A carefully designed(see value engineering) production process which involves low inventory(see JIT), quick change setups(see SMED), and short production lines(see cellular manufacturing), where the capacities of the various components of the line are well matched for the products to be produced.

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 $b = 0.322$. If a firm knows that a learning curve applies to its production, and the firm faces competition, then the firm should price low at the beginning of the life of a product so as to gain the experience so that its cost of production will be reduced quickly.

Left on the table: The gap between the winning bid and the second best bid in a sealed bid auction where the price paid is the winning bid. It is the amount of money the winner wasted because the winner did not have perfect information about the competition.

Letter of Credit: A document from a reputable bank to party A, saying that party B has a specified amount of money on deposit, and that the bank will pay this money to A upon the presentation of appropriate documents. A letter of credit may be useful in international purchases where party B wants to purchase something from party A in a

different country. A letter of credit may be useful when parties A and B do not have enough information about each other's financial condition to trust each other, however, both parties trust the bank. See also Escrow.

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. LIFO is thus very popular in the U.S., however, in the rest of the world, e.g., see IFRS, LIFO is not widely used. 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.

Lift table: A platform which can be raised or lowered, on which a pallet is placed as the pallet is filled or emptied. The raising of the platform allows a worker to place cases or other items on the pallet without stooping. The platform may also be rotatable to allow for easier access. See also Palletize.

Lift truck: See forklift.

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. LP is the fundamental optimization method underlying most optimization methods in supply chain management.

Line item: One line in a purchase order requesting a certain amount of one SKU. The transaction volume of a warehouse or DC is frequently measured by the number of lines per day that are picked.

Linear loss function: = expected value of Max$\{0, X- S)\}$, where X is a random variable, e.g., demand, and S is a threshold, e.g., the stock level. So 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 @PSL(z). For a Poisson distribution with mean D, it is given by @PPL(D, S). If $F(z)$ and $f(z)$ are the c.d.f and p.d.f. of the standard Normal, then @PSL(z) = $z*F(z) + f(z) - z$.

Liter: Standard measure of volume outside of U.S. Equal to .26 gallon.

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 prefer 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. For LTL delivery with multiple trucks you want to assign to the same load, customers who are close together, see for example the Clarke Wright savings heuristic.

Logarithmic distribution: A good probability distribution for modeling the number of units in an order. It has a single parameter p. Prob{an order is for x units} = $(1-p)^x/[-x*\ln(p)]$, for $x = 1, 2, \ldots$If we define $w = (p-1)/\ln(p)$, then the mean is w/p and the variance is $w*(1-w)/p^2$. See also Compound Poisson distribution.

Logistics curve: A "lazy" S curve that is convenient for representing a variety of things such as sales as a function of time for a new product as it first struggles to get attention in the market place, then catches on and rapidly becomes popular, and then later levels off. The mathematical form is:
$$y = (a + be^{cx})/(1 + de^{cx}), \text{ where } e = 2.71828182846.$$
If $c > 0$, then for $x << 0$, y approaches a, while for $x >> 0$, y approaches b/d. See also Bass model. The Logistics curve is also sometimes used to estimate the probability that a customer will pay his bill as a function of his normalized credit score x. In this case $a = 0$ and $b = c = d = 1$. See Logit model.

Logit model: A statistical technique frequently used in deciding whether to grant or deny credit to a prospective customer, or to estimate the probability that a given type of customer will buy our product. Given n different features of customer i, $x_{i1}, x_{i2}, .. x_{in}$, the logit model determines weights $w_0, w_1, \ldots w_n$, to compute a score $s(i) = w_0 + w_1 * x_{i1} + \ldots + w_n * x_{in}$. Prospects with a high score are granted credit; prospects with a low score are denied credit. Probability of being bad (0), (or probability customer i will not buy our product, is based on the logistics distribution and is given by: Prob{ i is bad $| s(i)$} = $1/(1 + e^{s(i)})$. Given empirical data, maximum likelihood methods can be used for estimating the weights, $w_0, w_1, \ldots w_n$. See also Probit model, multinomial logit 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 portion of its load at each stop.

LTPD(Lot Tolerance Percent Defective): A low quality threshold. See AQL.

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*MAD.

Makespan: The time until the last job is finished when scheduling a finite set of possibly precedence related set of jobs.

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. Used in measuring forecast error.

Margin: The ratio [(Selling_price/unit) – (Cost/unit)]/(Selling_price/unit), usually stated as a percentage. In contrast, also see Markup.

Markup: The ratio [(Selling_price/unit) – (Cost/unit)]/(Cost/unit), usually stated as a percentage. In contrast, also see Margin. In setting Markup, the essential rule to remember is that $sales – Cost_of_goods = Other_expenses + Profit. If Markup is written as a fraction, e.g. .25, then we must have loosely speaking: (1+Markup)*(Cost_of_goods) – Cost_of_goods = Other_expenses + Profit. A major component of Other_expenses may be interest expense. In a warehousing situation one component of interest expense is interest on capital tied up in inventory. A product that sits in inventory longer should tend to have a higher markup. Thus, for setting the markup for a specific product, you may want to use a rule something like Markup = Minimum_markup + (interest_rate/year)/(Turns/year). E.g., if some product averages one turn/year, then Markup should at least include the interest expense for one year.

Maquiladora: Mexican manufacturing plant near the U.S. border.

Marshalling yard: See Classification yard.

Martingale: If the expected value of demand tomorrow equals the observed demand today, then the demand process is said to be a Martingale. If the expected value of demand(or price of something) tomorrow is greater than or equal to the observed demand(or observed price) today, then the process is said to be a submartingale. Another example of a process well represented by a Martingale is forecasting tomorrow's temperature.

MaxiCode: A two-dimensional bar code used by UPS and other firms in the transportation industry. The code is about one inch square has a distinctive bullseye in the center. It can store about 93 characters of data, including a country code, a postal/ZIP code, plus optional information such as a tracking number. Other popular 2-D codes are PDF 417 and Data Matrix. For more details see www.aimglobal.org.

Maximum Likelihood Estimation(MLE): A very general statistical method for fitting a model to data. Given a set of observations, x_1, x_1,…,x_m, e.g., of sales, and an assumed general form of statistical model, e.g., Normal with mean μ and standard deviation σ, MLE chooses values for the parameters so as to maximize the probability, or "likelihood", that the observed data would have been drawn from the distribution with those parameters. For example, if the assumed distribution is Normal, then MLE will choose μ and σ as the mean and standard deviation in the observed sample.

Metcalfe's Law: The observation that the usefulness, and thus probably the demand, of certain 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 (Palo Alto Research Center).

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.

Mezzanine: A second level or floor, usually added later, in a warehouse with a high ceiling. The mezzanine level exploits space that might otherwise go unused.

MHz(Mega Hertz): Million cycles per second.

MICR(Magnetic Ink Character Recognition): A form of character recognition and document identification based on detecting characters printed with magnetic ink.

Used mainly for identification of checks. See also AIDC.

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. For example, baby food that arrived by truck from a baby food manufacturer and diapers from a diaper manufacturer may be combined onto a single truck going to a supermarket.

Money left on table: For a buyer, the amount he paid minus the seller's reservation price. For a seller, the buyer's reservation price minus what was actually paid. In a "pay what you bid" sealed bid auction, the winning bid minus the second highest bid.

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 unsuccessful.

Most Favored Nation: See Favored Nation.

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.

muda: A Japanese term for waste. More generally a management philosophy of continually trying to eliminate wasteful activities. See also kaizen;

Multi-block tariff: a cost structure in which the cost per unit depends upon the quantity ordered. Specifically, the possible order quantities are partitioned into a number of blocks, with a given cost per unit in each block. See also quantity discount.

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

Multinomial logit model: A model frequently used in marketing to predict which one of several products a customer will buy, based on the customer's characteristics. Each customer i, or market segment i, is presumed to be described by k different features, x_{i1}, x_{i2}, .. x_{ik}. The x's may measure attributes such as age, income level, education level, etc. Given P different products, the multinomial logit model computes a score, $s(i,j)$ for customer i and product j. By some mechanism, e.g., based on empirical data, we estimate weights w_{0j}, w_{1j},… w_{kj}, for $j = 1, 2, ..,P$. to compute the score $s(i,j) = w_{0j} + w_{1j} * x_{i1} + … +w_{kj} *x_{ik}$. The multinomial logit model then claims that the probability that customer i will choose product j out of all P products is $e^{s(i,j)}/(1 + \Sigma_{t=1..P} e^{s(i,t)})$. It follows that the probability the customer will buy none of the products is $1/(1 + \Sigma_{t=1..P} e^{s(i,t)})$. Given empirical data, maximum likelihood methods can be used for estimating the weights, w_{0j}, w_{1j},… w_{kj}. You can think of $rp(i,j) = e^{s(i,j)}$ as the relative preference for product j by customer segment i, with the relative preference of buying nothing as 1. A common assumption is that if you offer a subset of all possible products, the probability a specific consumer will purchase a particular product among the available products is proportional to her

relative preference for the product. Denoting the "purchase nothing" product as product 0, suppose consumer i has the follow (product,preference) pairs $(j, rp(i,j))$ = (0,1), (1,5), (2,8), (3,4), (4,7). If we offer only products 1 and 3, then the probability consumer i buys product 1 is $5/(1+5+4) = .5$, the probability she buys product 3 is $4/(1+5+4)= .4$, and the probability she buys nothing is $1/(1+5+4) = .1$. This model has the feature that if we: a) introduce a new product it may "steal" demand from existing products, and, b) drop an existing product, some of its lost demand may be "recaptured" by remaining products.
See also Probit model, logit model, consumer choice, assortment planning.

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.

Mystery shopper: a part time agent hired by a firm to test either its own product or service or that of a competitor. The mystery shopper is given a check list of products to buy or transactions to make at a particular retail outlet. The mystery shopper records various price and quality related aspects of the transaction, such as time to perform the transaction, whether the sales clerk was familiar with a particular feature of the product, or asked if the shopper wanted to buy the extended warranty, etc.

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 equibrium: a situation in which no player, e.g., supply chain partner, can improve his utility unilaterally, e.g. by changing his prices or his production quantities.
It need not be Pareto optimum. A special case is a Stackelberg equilibrium.

nautical mile: 6076.11549 feet=1852 meters, as opposed to 5280 feet in a regular mile.

NCS: Natural color system. A system, based in Sweden, for representing colors in such things as displays and logos. See also CMYK, HTML, Pantone, and RGB color.

Negative binomial distribution: a probability distribution that is commonly used in inventory management systems for modeling the number of units of a product demanded per day. It has two parameters p and k. If x is a possible number of units demanded per day, for $x = 0, 1, 2,…$, then the probability that demand is x is

$p^k(1-p)^x(k+x-1)!/[x!(k-1)!]$. If we define $P(x) = \text{Prob}\{\text{demand} = x\}$, then observe that $P(0) = p^k$, $P(1) = P(0)k(1-p),\ldots, P(x) = P(x-1)(k+x-1)(1-p)/x$.
The mean is $k(1-p)/p$, and the variance is $k(1-p)/p^2$. If actual demand has mean μ and variance σ^2, note that this corresponds to $p = \mu/\sigma^2$ and $k = p\mu/(1-p)$. Note that k is not required to be an integer. If k is integer, then the negative binomial distribution is sometimes called the Pascal distribution. The negative binomial is a special case of the Compound Poisson distribution for which the orders or batches arrive at rate $-k*\ln(p)$ and the mean number of units in an order is $(1-p)/[-p*\ln(p)]$, and Prob{an order is for x units} $= (1-p)^x/[-x*\ln(p)]$, for $x = 1, 2, \ldots$This distribution of order size is known as the logarithmic distribution. Another interpretation of the negative binomial is: 1) demand on day t is drawn from a Poisson distribution with mean μ_t, where μ_t is a random variable; 2) μ_t is chosen from a Gamma distribution with mean μ and variance $= \sigma^2 - \mu$. Demand then is negative binomial distributed.

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 airlines, 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.

Non-constant-sum game: A situation involving two or more 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. See also Prisoner's dilemma, zero-sum game.

Normal distribution: a distribution that tends to be a good representation of the sum of a large number 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: $\exp(-z*z/2)/2.506628275$. 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 for an NP-hard problem. An example of an NP-hard problem is the TSP, that is, how to have a truck visit N stops so it travels the least distance.

NPV(Net present value): Given an interest rate, e.g., cost of capital, of i per year, the net present value of a payment $\$X$ occurring n years from now is $\$X/(1+i)^n$. A standard way of accepting or rejecting a proposed project is to compute the NPV of all cash payments associated with the project and then accept or reject depending upon whether the NPV is positive or negative.

Nucleolus: 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(or the profit is more) if the players cooperate. Suppose customers A, B, and C, are each to receive a delivery. One truck is capable of making one trip to cover all three, however, different truckers could deliver to just one customer are any two. Suppose the cost of delivering to any combination of the three customers is: {A}:$81, {B}: $82, {C}: $83, {A,B}: $123, {A,C}: $122, {B,C}: $121, {A,B,C}: $189. E.g., making a single trip to serve A and C but not B costs $122. Making one trip that serves all three costs $189. Clearly, total cost is minimized if a single trip is used to make all three deliveries. Suppose, each customer is charged 189/3 = $63. Customers B and C might be unhappy with this and try to "break ranks" because they are being charged together $126, whereas they could hire a truck for the two of them for just $121. This would, however, leave customer A "stranded" and forced to pay $81 to get his shipment. The Nucleolus solution is to allocate costs so that the maximum temptation to break ranks is minimized. The allocation that does this is to charge $64 to A, $63 to B, and $62 to C. Notice that the "temptation to "break ranks" for the coalition {A,B} is $64 + 63 - 123 = \$4$. Likewise, for {A,C} the overcharge is $64 + 62 - 122 = \$4$, and for {B,C} the overcharge is $63 + 62 - 121 = \$4$. In contrast, the Shapley allocation for this problem is $63 to each of A, B, and C. Under the Shapley allocation, B and C are tempted to break ranks by the temptation of saving $63 + 63 - 121 = \$5$. The above example was interesting because the core was empty. The Nucleolus allocation is of interest in such situations when the core is empty, but the solution wherein everyone cooperates is nevertheless the least total cost solution.

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.

NWPCA(National Wooden Pallet & Container Association: see www.nwpca.com .

OCR(Optical Character Recognition): A form of character recognition and document identification. See also AIDC.

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 were 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.

OPIS(Oil Price Information Service): A price index system widely used in the petroleum industry for setting prices in supply contracts for products such as gasoline, diesel, LP-gas, jet fuel, crude, propane, kerosene, ethanol, and biodiesel.
See www.opisnet.com.

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. See also, service level.

ORM-D (Other Regulated Materials-Domestic): Goods that otherwise might be classified as hazardous, that have been repackaged in smaller, less dangerous sizes, ready for direct use by the consumer. Examples include pressurized aerosol cans, paint, aftershave lotion, fingernail polish remover, and more.

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. See also, inbound.

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, maintenance, customer contact, 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 quickly and 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. See also Coase's Law.

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 on which goods are placed so they can be picked up by a forklift to be placed in storage or on a truck. The most common size in the U.S. has standard horizontal dimensions of 40 in. by 48 in. (1016mm by 1219mm). This is standard in the U.S. grocery industry and elsewhere. These dimensions allow two pallets to be placed side by side in a standard U.S. truck trailer. A size of 42 in. by 48 in. is common in the U.S. chemical industry. Half-size pallets of 20 in. by 48 in. are also sometimes used. ISO recognizes six pallet horizontal dimensions: 1) 40 in. by 48 in., 2) 1000 mm by 1200 mm (common in Europe and Asia), 3) 1165 mm by 1165 mm (common in Australia), 4) 1067 mm by 1067 mm (42 in. by 42 in., common for paint in the U.S.), 5) 1100 mm by 1100 mm (common in Asia) 6) 800 mm by 1200 mm (common in Europe). See also, the 463 pallet. Most pallets have allow four way entry of the tines of a fork lift.
More recently, plastic based pallets have been introduced.
Although more expensive, plastic pallets last longer and have less danger
of carrying dangerous insects from one part of the world to another. To prevent
the spread of pests, some countries require wood pallets to be treated at 56 degrees
centigrade and or fumigated with methyl bromide. Wood pallets receiving this heat

treatment are stamped HT. Pallets treated with methyl bromide are stamped MB. Plastic pallets can be formed 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. Another factor in deciding between wood vs. longer lasting pallets is whether the pallets are in a closed loop within your company or if you ship one way and never get the pallets back. In the latter case, the cheaper pallets make sense. Some pallet designs include an RFID device imbedded in the pallet so that the pallet can be easily tracked through a supply chain. 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 plastic shrink wrap, so that the assembly is stable during shipment. See also: Lift table. A pallet with goods placed on it is sometimes called a skid.

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 $D*L$.

Panamax ship: The largest ship that can pass through the original Panama canal. The maximum dimensions are: Width: 106 feet(32.3 meters); Length: 965 feet(294 meters); Height: 190 feet(57.9 meters), Draft: 39.5 feet(12 meters).

Pantone system: A standard set of 1114 precisely defined colors, see http://www.pantone.com. For example, in the labeling of hazardous material, U.S. federal standards suggest that Red labels should be Pantone 186, Orange should be Pantone 151, Yellow(corrosive or radioactive) is Pantone 109, and Green is Pantone 335. In general, if you need to specify to a supplier, printer, or manufacturer the color you want used for a label, logo, etc., you can simply give the Pantone number. See also: RGB, CMYK, NCS, and HTML color.

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.

Pascal distribution: see negative binomial distribution.

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, QR code and MaxiCode. For more details see 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.

Pendulum arbitration: See FOA.

Percent done rule: A forecasting rule for predicting the sales of a seasonal product during the second period of a season, based on the sales observed during the first period of the season. E.g., based on the observed sales during the period November 20 to December 10, we may want to forecast the sales during the period December 11 to December 25. In its simplest form, we estimate, e.g., from data, the fraction k of the full season demand that historically occurred in the first period. Suppose $k = .4$, corresponding to being 40% done with sales after the first period. Then, if we see a demand of 80 units in the first period, we would predict second period demand of $80*(1-.4)/.4 = 120$ units of sales in the second period. A variation of this rule was developed by Fisher et. al. for the Sport Obermeyer apparel company. To describe this variation, we first estimate, e.g., from historical data, the four numbers:

μ = expected total demand over both periods,
k = expected fraction of the demand occurring in the first period,
δ = correlation in period 1 and period 2 demand,
ρ = correlation in period 1 and total demand.

Then we compute:

$\mu_1 = k\,\mu$ = expected first period demand,
$\mu_2 = (1 - k)\,\mu,$ = initial expected first period demand,
$\sigma_2 = \sigma[(1- \rho^2)/(1- \delta^2)]^{0.5}$ = initial estimated second period standard deviation,
$\sigma_1 = \sigma\rho - \sigma_2\,\delta$ = first period standard deviation.

Once we see period 1 demand, D_1, we update our forecast of period 2 demand with:

$E(D_2/D_1) = \mu_2 + \delta\,\sigma_2\,(D_1 - \mu_1)/\sigma_1$,
Updated s.d. for period 2 $= \sigma_2\,(1 - \delta^2)^{0.5}$

Notice that if the correlation between period 1 and period 2 demand, δ, is 0 then the formula does not change our a priori estimate of period 2 demand after observing

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period 2 demand. Notice that if ρ is small, it means most of the variability is in period 2, whereas if ρ is large, it means most of the variability is in period 1. Also, if the standard deviation in period 1 demand, σ_1, is large, then we place less weight on observed period 1 demand when updating our estimate of period 2 demand. See also Bass model and exponential smoothing.

Perpetual inventory: The inventory that the computer information system thinks is on hand based on the update formula:
$inventory(t+1) = inventory(t) + official\_receipts(t) - official\_withdrawals(t)$. Due to unrecorded transactions, such as shrinkage, the perpetual inventory will tend to get out of step with actual physical inventory, so from time to time some sort of "physical inventory" must be performed. See also: cycle counting.

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 the Polaris Fleet Ballistic Missile development program directed by Admiral William(Red) Raborn. The fact that Admiral Raborn's wife had the nickname Pert, may be relevant.

PET(PolyEthylene Terephthalate): Type of plastic used to make beverage containers. If your plastic bottle is made from clear plastic, it is probably made from PET. PET is resistant to acids but not bases. A bottle made from PET is marked with a "1" recycling code at the bottom. Recycled PET can be made into fibers for carpeting for example. To a modest extent, PET may also be recycled back into making containers. See also HDPE, PVC, and LDPE.

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. Two extreme picking strategies are pick-to-order and zone picking. In pick-to-order, one picker is assigned to each order and that person wanders around to warehouse to pick all items in the order, thus the picker also does the sorting. In zone picking, one picker is assigned to each zone of a warehouse and that picker picks all items from that zone needed during a particular shipping period, e.g., a day or a "wave", and feeds the items into a collection system, after which the items are sorted, perhaps automatically, by order.
See also pick-to-light, bucket brigade, eaches, piece-pick, and wave.

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.

Piece-pick: In a warehouse, the picking of a single item, rather than a case. Sometimes also known as split-case or broken case picking. See also eaches.

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. In contrast, see also: Echelon inventory.

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. See also Apollo from IRI and Spaceman from A.C. Nielsen.

PLC(Programmable Logic Controller): See Ladder logic.

PMPA(Petroleum Marketing Practices Act): A U.S. federal law that essentially prevents one party in a petroleum supply contract from arbitrarily canceling or not renewing a supply contract. See also OPIS.

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 simple 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 $k = 0,1,2,\ldots$ 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. See also Compound Poisson, Negative Binomial.

Poka yoke: Japanese term meaning literally error avoidance, or mistake proofing. A collection of ideas popularized by Shigeo Shingo for designing a product or production process so that it is impossible to use it incorrectly. An example is the two pronged electrical plug. The one prong is larger than the other so that it is impossible

to insert the plug into the electrical outlet in the wrong orientation. See also jidoka.

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. POS data is usually obtained by scanning the UPC of the product as it is sold.

Postponement: A rearrangement of 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. An example is the mixing of paint in a hardware store to obtain a particular color desired by a customer. If no mixing were done in the store, but rather at the paint manufacturer, then each store would have to carry a large number of different premixed paints. For some products you can think of the product as consisting of a common base module needed by all customers plus one or more personality modules. Postponement is worthwhile if the base module is expensive but the personality modules are cheap and easy to add as we observe customer preferences. The ultimate postponement is the "one size fits all" approach. If the power supply in an appliance can automatically detect the type of electrical supply, e.g., 120 vs. 240 volts, 50 cycle vs. 60 cycle when the appliance is connected to the electrical supply, then only one type of product need be carried.

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 an 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. See also: TAPI

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 or 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 in separate cells. 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 receives a severe sentence. This is an example of a nonconstant sum game. Another example is two suppliers, e.g., crude oil producers. If both restrict output, the price will be high and they both makes lots of money. If one producer, however, cheats by quietly increasing his output, he will make even more money. See bi-matrix game.

Private fleet: An operational style in which a firm that ships goods, owns its own fleet of vehicles, typically trucks, to carry its goods. The advantages of owning one's own fleet are several: The shipper has more control of shipping decisions and thereby can give better service. Errors in shipping are easier to monitor. If the shipper's product is somewhat unusual, e.g., low density, the shipper can acquire special vehicles appropriate for this product that might be difficult to find in the commercial carrier marketplace. Finally, vehicles, especially trucks, provide free billboards for advertising the shipper's products. The major disadvantage of having one's own fleet is the fixed ownership costs that must be incurred. If the fleet is small, it is difficult to overcome these fixed costs. Examples of capabilities that the fleet owner needs are: vehicle maintenance capabilities, driver hiring and training, scheduling and routing capability. With regard to routing, the shipper may need the ability to solicit backhauls to fill otherwise empty returning vehicles.

PRO number:(Progressive Rotating Order). An identifying number assigned to each order that a truck carrier carries. A shipper can track an order with the carrier by specifying its PRO number.

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.

Producer risk: Probability a high quality lot is rejected. See AQL.

Profit sharing: An agreement for sharing profit among participants, e.g., employer and employees, manufacturer and retailer, etc. The general goal of the agreement is to increase the total profits of the entire group of participants. An agreement is incentive compatible if for each action that a participant is considering taking, if that action increases total profits, then it also increases the profit allocated to that participant under the agreement. Major problems in designing a profit sharing plan are:
a) measuring the private costs incurred by participants when taking an action, e.g. how much pain and inconvenience is incurred by an employee to work a little extra on occasion, be more careful, etc.,
b) measuring the benefits to the group of an action, e.g., advertising by a retailer, and

c) keeping the agreement simple enough to be understandable.

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. A manufacturer may do a promotion to its retailer customers, or a retailer may do a promotion to its retail customers. 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.

Put Option: An contract between two parties A and B that gives A the right, but not an obligation, to sell to B a specified quantity of some commodity at a specified price. It is a European option if the right to sell is for a specific date. It is an American option if the right to sell exists for any day up to the expiration date of the contract. See also Call option.

PVC(PolyVinyl Chloride): A stiff plastic, highly resistant to acids and bases; often used for piping and similar applications. Because of its chlorine content, it may produce toxic fumes when burned. Also, because of its chlorine content, it should not be used in applications where it comes in contact with food. Items made from PVC are typically marked with a "3" recycling code. See also: PET, HDPE, and LDPE.

QA(Quality Assurance): The process and procedures for ensuring the quality of a product.

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.

QOS: Quality of service. A measure of how well someone's service achieves a quality target.

QR code: A printed two dimensional code originally from Japan. QR stands for Quick Response. See also UPC, AIDC, Bar code, Data Matrix code, MaxiCode and PDF417.

QRM(Quick Response Manufacturing): A production control system, intended to reduce lead times, that combines useful features of Kanban and MRP. It was developed at the University of Wisconsin, see: http://www.engr.wisc.edu/centers/cqrm/about.html.

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^2(R squared): A measure, between 0 and 1, of how well a forecast or regression line fits a set of data. An R^2 of 1 means a perfect fit. Numerically, it is $1 - $ (sum of squared errors about the forecast line)/(sum of squared errors about the mean). In words, R^2 is the fraction of the original variability or error in some naïve forecast statistic that is removed or explained by a more detailed forecast model. An R^2 of 0 means the fancy forecasting model does not better job of forecasting than the simple "predict the mean" forecast, whereas an R^2 of 1 means the fancy forecast is perfect.

Rack: The shelf-like storage structure usually used in a warehouse or DC.

Rack jobber: Someone outside a store organization who manages a set of shelves or rack of products in the store. Typical products sold are items with a shelf life of at least a week, e.g. magazines, health and beauty aids, candy, and other snacks. The store supplies two functions: a) shelf space, and b) processing of the sales transactions for items sold. The rack jobber provides all aspects of inventory management, including finding a supply source, warehouse storage, delivery from warehouse to the store, and removal of unsold items. By use of rack jobbers, a store is able to sell a wide variety of products with little investment other than that for the store structure and fixtures and the cash/sales register system. The rack jobber typically operates

from a truck, visiting each store regularly, e.g., weekly, and restocking the rack. The financial arrangements have several possible components: a) a slotting fee paid by the rack jobber to the store, -essentially a rental fee for the space used by the rack jobber, b) a per unit cost paid by the store for each item delivered to the store, c) a per unit payment by the store to the rack jobber upon sale of an item, d) a refund on unsold items removed from the rack. See also: consignment.

Rag trade: Slang term for clothing industry.

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. A rain-check is not only good for customer good will but it also provides two kinds of information to the retailer: a) it gives the retailer a more accurate measure of true demand than simple sales data would otherwise give, and b) it may make the retailer be aware of when the retailer is physically out of stock, even though the retailer's inventory records may incorrectly suggest that the retailer has stock.

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 because the producer's revenue would not cover his fixed(as well as variable) costs. 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 ≥ fixed + variable cost of producing them.

RAS(Russian Accounting Standard): Accounting rules used in Russia. It tends to be more cash based, e.g., income is recognized when cash is received and expenses are recognized when cash is paid.

RBRC: Rechargeable Battery Recycling Corporation. A reverse logistic operation for recycling old rechargeable batteries. See www.rbrc.org. Manufacturers who participate in this program place an RBRC seal on their batteries. When such a battery loses its ability to hold a charge, the battery may be dropped off at any retail outlet, e.g., an electronics, hardware, or office supply store that participates in the program. Battery types supported are: Nickel-Cadmium, Nickel-Metal-Hydride, Lithium Ion, and Small-Sealed-Lead.

Reach: See Exposures.

Reefer: Refrigerated container, trailer, or truck.

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

Reservation price: For a buyer, the maximum the buyer is willing to pay for an object. For a seller, the minimum the seller is willing to accept for his product.

Revenue management: a collection of techniques for increasing the revenue from the sale of a product or a group of related products. 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, a 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, bundle 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. This is the technology that is used in automatic toll collection from cars on a highway and badges used to control entry to a building. The reader need not touch the label in order to read it. Typical storage content is from 126 to 992 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 the tags 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. The 125 KHz frequency is

used in some systems. In many uses the tag can contain the serial number of the individual item. This is a big step up as compared to a bar code, where all similar items have the same bar code. The use of RFID introduces all sorts of privacy issues in that individual items can be tracked by anyone with an RFID reader.

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.

RFP(Request For Proposal): A variation of an RFQ in which the author is somewhat less certain of the specifications. The response is expected to be more in written rather than quantitative form. That is, the response is more of the form: "Here is how we propose to satisfy your need."

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.

RGB color: A color representation system based on using combinations of Red, Green, and Blue primary colors. It is used for example in color displays. Each pixel consists of three subpixels of the RGB colors. It is an additive color system in that if all three colors are turned on, the human eye sees it as white. See also: Pantone, CMYK, NCS, and HTML color.

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.

Rockwell hardness: When purchasing a material such as steel that must be abrasion resistant or is to be used for cutting or forming, the hardness of the material may be specified in the contract in terms of Rockwell hardness. There are several different Rockwell scales. All scales measure the amount of plastic(permanent) deformation that occurs when a diamond cone or a hard steel ball is pressed against the material. For hard materials such as tool steel, the C scale is common. C scale hardness is measured by pressing a diamond cone into the material under a 150 kg load. The depth of the indentation is then measured. The Rockwell hardness is then $100 - .002*d$, where d is the depth of the indentation measured in millimeters. A typical knife blade might have a hardness of RC55. A tool steel used for metal cutting might have a hardness of RC62.

ROI: Return On Investment. A not always well-defined measure of the attractiveness of

an investment. The most straightforward definition is that it is the interest rate of a bond such that you would be financially indifferent between investing your money in the investment in question vs. investing the same amount of money in the bond.

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. Public key encryption simplifies the process of doing secure electronic commerce.

RTLS(Real Time Location System): An extension of RFID for locating items in close to real time. An RTLS tag on an item broadcasts a signal, including the ID of the item periodically, e.g., once per minute, or when queried. If three or more receivers receive the signal, then the location of the item can be accurately identified by triangulation, using some combination of observing signal strength or on precisely measuring time delays. RTLS is useful for locating items that may move regularly, such as containers and forklifts.

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, 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.

SBAR(Situation-Background-Assessment-Recommendation): A format for communicating in certain operations, typically in the health industry or in airlines, where important information is to be transmitted, typically verbally, as in a cockpit or between a nurse and a doctor. Loosely speaking the presentation is: here is the situation, here is the background, here is my assessment, here is my recommendation.

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, valves, etc., 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.

Service level: In an inventory setting, the fraction of the demand instances in which we had sufficient product to satisfy demand. There are at least three interpretations, see: a) item fill rate, b) line item fill rate, and c) order fill rate. For a given inventory policy, typically (a) > (b) > (c). To put some numbers on things, suppose we have two products each with independent Normal demand with mean 60 and sd 20 (say demand between restockings). Suppose we stock 80 units for each product, i.e., $z = 1$ sd above the mean. Then, using a Normal table and Normal linear loss function, we can compute:

    item fill rate = .97 (1 - (expected lost sales)/mean demand),
                              estimating lost sales using linear loss function, sd*PSL(z))
    line fill rate = .84 (left tail of Normal table at $z = 1$)
    order fill rate = .71 (line fill rate1 * line fill rate2)

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

A unique feature of the Shapley value allocation is that if there are multiple cost types to be allocated, then the Shapley allocation adds over these cost types. For example, suppose that customers A, B, and C above have to buy not only transportation but also have to buy the raw materials from a separate supplier. Further, this raw material supplier gives quantity discounts. Thus, it is worthwhile for A, B, and C to cooperate on raw material purchase. Given the quantity discount, there is the second question

of how to allocate the cost of the raw materials among A, B, and C. A unique feature of the Shapley allocation is that if you use the Shapley allocation to determine the allocation of raw material cost, you get the same total allocation for each of A, B, and C as if you had lumped transportation costs and raw materials costs together and then computed the Shapley allocation on the combined cost.
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.

Short Interval Scheduling: A work assignment system in which a supervisor assigns work to workers in relatively short intervals of about a half hour. This requires some way of estimating the work content of each task. It allows management to closely monitor progress and become aware of problems quickly.

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. See palletize.

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(Systeme International d'Unites) 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($kg*m/s^2$), joule(J) for work($kg* m^2/s^2$), and watt(W) for power(m^2*kg/s^3). Standard prefixes for successively larger/smaller units are: deka(10), hecto(10^2), kilo(10^3), mega(10^6), giga(10^9), tera(10^{12}), peta(10^{15}), exa(10^{18}), deci(10^{-1}), centi(10^{-2}), milli(10^{-3}), micro(10^{-6}), nano(10^{-9}), pico(10^{-12}), femto(10^{-15}), and atto(10^{-18}). For more information see http://physics.nist.gov/cuu/Units/units.html.

SIC code: Standard Industrial Classification. A six digit code used for classifying industries in the U.S. SIC is being replaced by a common North American Industry Code, NAICS, which will be applicable to Canada, the U.S., and Mexico. See http://www.census.gov/epcd/naics02/naicod02.htm. Air, rail, water, truck, and pipeline industry codes are of the form respectively: 481xxx, 482xxx, 483xxx, 484xxx, and 486xxx. For example, 484xxx is trucking in general; 484121 is long distance FTL; and 484122 is long distance LTL.

SIS: See Short Interval Scheduling.

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 that 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.

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.

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.

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 repairperson 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 process 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. To avoid congestion, two high volume SKU's that tend not to be ordered together should be stored in different aisles. The slotting decision interacts with the inventory decision by way of the facing decision, that is, how many facings to allot to a SKU. If a particular SKU can be stored 5 deep in a slot, and you decide to carry 7 units of the SKU, then you must allocate 2 facings to the SKU. 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. SMED 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 cams and "slip on and tighten" key-hole connectors are used.

Sole sourcing: The arrangement by which a customer gets all of its product from a single supplier. Sole sourcing is administratively simpler. E.g., if there is a problem with product, there is less ambiguity as to who supplied the product. A disadvantage of sole sourcing is that if your single supplier has a supply problem, e.g., a strike, then there is less flexibility to quickly turn elsewhere for alternate supply.

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(typically in bar code form) on the package. The system then pushes the package off the conveyor at an off ramp appropriate for the package's destination. If the main conveyer recirculates, then it may be referred to as a "dogtrack".

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

Soundex: A system for encoding a person's last name into a four character code. It is useful, for example, in dealing with customers by phone. Names that sound similar, such as Smythe and Schmitt encode to the same Soundex code. If two different salespersons dealt with the customer, they may have spelled the customer's name slightly differently. If the customer is looked up by the Soundex code, you will probably be able to identify the customers in the database who might correspond to the current customer. The Soundex code consists of the first character of the person's name followed by three digits from 0 to 6. The rules are, after the first character:
a) disregard the letters a, e, i, o, u, h, w, and y. b) digits are determined by the rule:
  1: b, f, p, v
  2: c, g, j, k, q, s, x, z
  3: d, t
  4: l
  5: m, n
  6: r

c) disregard consecutive letters that have the same code, d) if necessary, fill with zeroes to get a four character code. Some example encodings are:

Gutierrez: G362
Goutteres: G362
Smythe: S530
Schmidt: S530

One of the earliest suggestions of a Soundex like system was the 1918 U. S. patent, number 1261167, by Robert Russell.

SOW(Statement Of Work): Typically part of an agreement between a customer and a vendor, specifying what will be delivered when. Usually the deliverable has a significant amount of intellectual content, such as a consulting report or a piece of software. Details in the SOW may cover the format of the deliverable, e.g., paper vs. electronic form, what is to be provided by each party, e.g., who provides the office space, the computing power, the data collection effort.

Spaceman: Planogram software from A.C. Nielsen.

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.

SQL(Structured Query Language): The standard format for requesting data from a database, e.g., from Oracle, SQL Server, MS Access, etc. An example request is: SELECT name, phone_number FROM customer_file WHERE area_code = 847.

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.

Standard deviation: Square root of variance. See Variance.

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.

Stockout: When a demand occurs and there is no inventory to satisfy it. See also backorder.

Stuttering Poisson distribution: A compound Poisson distribution for which the batch or order size has a Geometric distribution.

sunk cost: a cost which is no longer avoidable.

Supply Chain: see channel.

Swag: Free items given to promote a vendors's product, typically at events in the entertainment industry. Thus, purchasing agents might be given a bag of swag for attending or listening to a vendor's presentation. If the value of the contents are nontrivial, then its value must be reported as income for the recipient.

SWIFT(Society for Worldwide Interbank Financial Telecommunication: A worldwide cooperative of financial institutions for providing standardized communications, e.g., for doing wire transfer of funds as part of a purchase. Each member bank has its own SWIFT code. To send a wire transfer, the most important piece of information is to provide the SWIFT code of the recipient. See: www.**swift**.com .

T1 line(Trunk level 1): A data transmission capacity of 1,544,000 bits per second. 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.

Tachograph: A truck mounted recorder of time, speed, rpm, miles traveled, and perhaps other information such as brake activation, door opening and closing, etc. The recorded data may by useful in checking adherence to HOS rules, etc.

Takt time: The time available divided by the number of units to be produced. Presuming one wants to have steady production in a manufacturing facility, the Takt time is the time between successive units coming off the production line. Takt is a German word meaning to keep time, as in music.

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

TAPI(Telephony Application Programming Interface): A software library enabling a computer to interact with the telephone system, e.g., to send and receive faxes with business partners, allow a user to simply click on a customer's name on the computer screen to initiate a call to that customer, etc. See also: CRM, Predictive dialing, VOIP, Call center.

Tardiness: The amount of time by which a delivery or job completion is later than its due date. Formally: tardiness = max{0, Completion_time – due_date}.

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

Taylor, Frederick Winslow: (1856-1915) The father of "Scientific Management". The essence of his philosophy was finding the one best way of executing a particular task,

be it shoveling coal by a laborer or machining metal by a lathe. For example, with regard to shoveling, he estimated that the ideal amount to be moved in a shovelful was 21.5 pounds. So instead of supplying his workers with a single shovel type used for all materials, he supplied different sizes of shovels depending upon the density of material to be shoveled. With regard to machining metal, at Midvale Steel Company he experimented with about a half dozen different parameters, such as speed, tool feed rate, tool hardness and derived a close to optimal setting of the parameters for the type of material being machined. His improvements in metal machining were dramatic. His "one best way" with regard to manual labor was a predecessor of Time and Motion Study. He was one of the early proponents of piece-rate or piece-work compensation systems for labor. One of his colleagues at Midvale was Henry Gantt.

TCO: Total Cost of Ownership. A methodology for comparing two alternative systems for performing the same task. TCO is usually suggested and performed by a vendor who is selling a system that is ostensibly more expensive, but which may be in fact less expensive when one properly accounts for less obvious costs, such as the higher maintenance costs that are sometimes associated with a system that is cheaper up front.

Terminal: A distribution center(DC), usually one that does not carry inventory.

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, about 8.5 feet high, and about 8 feet wide . A 40 ft container is 2 TEU. See also: container.

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.

TLA: Three Letter Acronym. The scourge of the military and the federal government.

TMS(Transportation Management System): Software for helping manage 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.

TNOF(Title Not On Floor): In the book industry, an indicator that an sku is not in stock.

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 it 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. A tote may also be used for moving small products between work stations. Some totes may be collapsible so that they take less space when returned to the starting point. Alternatively, totes may be designed with tapered sides so that they nest when empty.

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.

Tramp ship: A cargo ship that does not follow a regular trade route but makes trips as demand arises.

Tranche: French for "slice". Term typically used in financial transactions, e.g., an auction, to indicate one of several bids, differing only along one dimension such as bid price(for a given quantity), or amount of risk, or rate of return, or maturity associated with the object.

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.

Transhipment: 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 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)/(average 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. If you need a bar code for your product see this group. 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. See also: 463 Pallet.

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, 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 provides not only the new computer to run the software but also installs it on the 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: (statistics) 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 $i = 1, 2, \ldots n$, and $xbar$ is the mean of the sample, then the sample variance is $\Sigma_i (x_i - xbar)^2/n$. Sometimes an algebraically equivalent, but numerically less accurate formula is suggested: $\Sigma_i x_i^2/n - xbar^2$. 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 populations size. The sample variance underestimates the population variance because the squared differences are taken with respect to the sample mean, *xbar*, rather than the (generally unknown) population

mean. If the population size is infinite, then an unbiased estimate of the population variance is $\Sigma_i (x_i - xbar)^2/(n – 1)$.

A useful result when dealing with the sum of two random variables, e.g., the pooled demand of two similar products, is that

$$Variance(D_1+D_2) = Variance(D_1) + Variance(D_2) + 2*Covariance(D_1,D_2).$$

Variance: (accounting) In accounting, a variance is the difference between actual and that predicted by standard. Usually there are several sub-classifications. E.g., a volume variance might be the variance in total cost due to a difference between the quantity predicted and the actual quantity. A labor variance might the variance in total cost due to the actual labor per piece being different from the predicted or standard labor per piece.

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.

VICS(Voluntary Interindustry Commerce Standards Association): A group devoted to the development of efficient standards for supply chain management, see http://www.vics.org/.

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.

VOIP(Voice Over Internet Protocol): Technology for routing voice calls over the

internet. This makes much more efficient use of a communication network because a) it uses no network resources when no sound is being sent, and b) the route used may vary from second to second so as to better exploit less utilized portions of the network. See also: TAPI.

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.

Wagner-Whitin algorithm: A method for choosing the periods in which to produce a product so as to minimize the sum of setup costs plus holding costs. It assumes that we know with certainty: 1) The number of periods, N, into the future over which we are planning, 2) the demand each period, 1,…, N, for the product, 3) the cost of holding a unit of product for one period, and 4) the fixed cost each period of setting up to produce the product if any product is produced. The method uses a dynamic programming/bootstrap approach, first finding the optimal solution for a one period problem, then for a 2 period problem, etc. The key idea is that if we know that the last setup occurs in period t, $t < N$, then the solution for the periods 1, 2,…,t-1 is the same as if we considered periods 1, 2,…,t-1 as a separate problem(which we happen to have already solved). One of its weaknesses is that it assumes infinite capacity.

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, or sections of a warehouse, may be specifically designed to handle refrigerated goods, frozen goods, high value/security goods, fruits and vegetables, flammable goods, or other hazardous materials. For example, warehouses that store fruits such as bananas may have special sealed rooms into which a trace of ethylene gas is introduced to accelerate the ripening process as needed. The main operations in a warehouse are 1) Receiving and inspection, 2) Slotting/put-away of received goods, 3) Inventory control and ordering, 4) Picking and packing of orders to be shipped, 5) Load construction and routing, 6) Shipping administration. See also WMS.

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.

Watt-hour: Standard unit for buying or selling electrical energy, equal to 3600 joules(see SI units), or energy corresponding to using one Watt of electrical power for

one hour.

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. If, say, a sortation system has30 slots then it is natural to accumulate orders into a wave until either you have 30 orders, or the next pickup by a general carrier, e.g., FedEx, UPS, DHL, etc. is imminent.

Waveless picking: In a highly automated DC with radio communication between the WMS and the pickers, a continuous picking and packing system may be used. Much higher throughput may be achieved for a given amount of labor and sorting hardware. Suppose the sortation system has *B* outlets to handle up to *B* destinations at once. At the beginning of the day, B orders are released to the pickers and each order is assigned to one of the outlets. As soon as an order is filled, its outlet can be reassigned to another order and this new order can then be transmitted to the pickers by radio. If the conveyor systems has significant storage capacity, e.g. via a recirculating dogtrack, more than B orders can be released to the pickers and the items already picked for an order not yet assigned to an outlet are simply stored or recirculated in the conveyor system.

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.

Weber problem: Given a set of customers, with each customer *j* having a sales volume v_j, and its location specified by its coordinates x_j, y_j, the Weber problem is to choose location coordinates x_0, y_0, for a single supplier so that the sum of the weighted distances to customers is minimized. The v_j are the weights used.
Mathematically the problem can be stated as:
Choose x_0, y_0 so as to Minimize $\Sigma_j\, v_j *d_j(x_0, y_0)$;
where $d_j(x_0, y_0)$ is the distance from customer j to the supplier located at x_0, y_0.
If we use straight line distances then $d_j(x_0, y_0)$ = square root of $[(x_0 - x_j)^2 + (y_0 - y_j)^2 \,]$.

WEEE(Waste Electrical and Electronic Equipment): A directive from the European Union(EU) that manufacturers of various electronic appliances must have a procedure for recycling the products that they sell in the EU. There are interesting logistics considerations here in that a manufacturer or distributor can contract with another logistics firm to provide the recycling system.

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.

Winter's method: A forecasting method that extends exponential smoothing to take into account a linear trend and multiplicative seasonality. Sometimes also known as Holt-Winter's method. The number of periods in a season cycle is L. The essential formulae are:

  Base level estimate using demand, D_t, up to period t:
    $B_t = \alpha*D_t / S_{t-L} + (1-\alpha)*(B_{t-1} + T_{t-1})$,

  Trend estimate:
    $T_t = \beta *(B_t - B_{t-1}) + (1 - \beta)* T_{t-1}$,

  Seasonality estimate:
    $S_t = \gamma * D_t / B_t + (1 - \gamma) * S_{t-L}$,

  Forecast ahead k periods:
    $F_{t+k} = (B_t + k * T_t)* S_{t+k-L}$.

  The smoothing constants, α, β, and γ are typically about 0.1.

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

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

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. Named after the American Standards Committee X12 which is responsible for EDI standards.

XBRL(Extensible Business Reporting Language): A data language, similar to XML, for submitting financial reports.

XML(eXtensible Markup Language): An "open", ISO standard data language, similar to but more powerful than HTML, for not only 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 XML are that, like HTML, it uses tags, and is tree structured, as illustrated by the following example:

```
<line item>
      <sku> b40104 </sku>
      <weight>
            <unit> kg </unit>
            <value>  2.1  </value>
      </weight>
      <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 and bi-matrix game.

Zero balance walk: A form of selective inventory auditing popular in retail stores. Periodically, e.g., once per week, a manager will make a tour of the store shelves, noting which SKU's are out of stock, i.e., have zero balance. For these SKU's the inventory records will be checked to verify that the information system also shows these SKU's to be out of stock (and on order unless the product is being discontinued.) A zero-balance-walk audit of the records takes a lot less work than a full audit, yet it does result in an audit of the small fraction of SKU's most likely to benefit from an audit. The regular use of a zero balance walk will tend to increase average inventory. If for some SKUs the actual inventory level is greater than the official record shows, while the actual inventory for others is less than the official record, then the zero balance walk will catch many of the SKU's for which the actual inventory is lower than the official record, and increase their inventory, however, SKUs for which the actual inventory is higher than the official record will remain undetected.
See also, shrinkage.

Zero defects: A quality assurance philosophy with the goal of zero defects. A key part of this philosophy is that whenever a defect is found, the cause of the defect is identified and then the process is changed so that a defect will not occur again as a result of this cause.

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 processed through its sorting system.