Production, Manufacturing and Logistics

(Engineering and Management)

Kay Weed

Arely Cazares

First Edition, 2012

ISBN 978-81-323-0973-4

Published by:
Academic Studio
4735/22 Prakashdeep Bldg,
Ansari Road, Darya Ganj,
Delhi - 110002
Email: info@wtbooks.com

Table of Contents

Chapter-1

Assembly Line

Modern car assembly line.

An **assembly line** is a manufacturing process in which parts (usually interchangeable parts) are added to a product in a sequential manner using optimally planned logistics to create a finished product much faster than with handcrafting-type methods. The assembly line developed by Ford Motor Company between 1908 and 1915 made assembly lines famous in the following decade through the social ramifications of mass production, such as the affordability of the Ford Model T and the introduction of high wages for Ford

workers. Henry Ford was the first to master the assembly line and was able to improve other aspects of industry by doing so (such as reducing labor hours required to produce a single vehicle, and increased production numbers and parts). However, the various preconditions for the development at Ford stretched far back into the 19th century, from the gradual realization of the dream of interchangeability, to the concept of reinventing workflow and job descriptions using analytical methods (the most famous example being scientific management). Ford was the first company to build large factories around the assembly line concept. Mass production via assembly lines is widely considered to be the catalyst which initiated the modern consumer culture by making possible low unit cost for manufactured goods. It is often said that Ford's production system was ingenious because it turned Ford's own workers into new customers. Put another way, Ford innovated its way to a lower price point and by doing so turned a huge potential market into a reality. Not only did this mean that Ford enjoyed much larger demand, but the resulting larger demand also allowed further economies of scale to be exploited, further depressing unit price, which tapped yet another portion of the demand curve. This bootstrapping quality of growth made Ford famous and set an example for other industries.

Concept

Assembly lines are designed for a sequential organization of workers, tools or machines, and parts. The motion of workers is minimized to the extent possible. All parts or assemblies are handled either by conveyors or motorized vehicles such as fork lifts, or gravity, with no manual trucking. Heavy lifting is done by machines such as overhead cranes or fork lifts. Each worker typically performs one simple operation.

According to Henry Ford:

”The principles of assembly are these:
(1) Place the tools and the men in the sequence of the operation so that each component part shall travel the least possible distance while in the process of finishing.
(2) Use work slides or some other form of carrier so that when a workman completes his operation, he drops the part always in the same place--which place must always be the most convenient place to his hand--and if possible have gravity carry the part to the next workman for his operation.
(3) Use sliding assembling lines by which the parts to be assembled are delivered at convenient distances.”

Lotus Cars assembly line as of 2008

Simple Example

Consider the assembly of a car: assume that certain steps in the assembly line are to install the engine, install the hood, and install the wheels (in that order, with arbitrary interstitial steps); only one of these steps can be done at a time. In traditional production, only one car would be assembled at a time. If engine installation takes 20 minutes, hood installation takes 5 minutes, and wheel installation takes 10 minutes, then a car can be produced every 35 minutes.

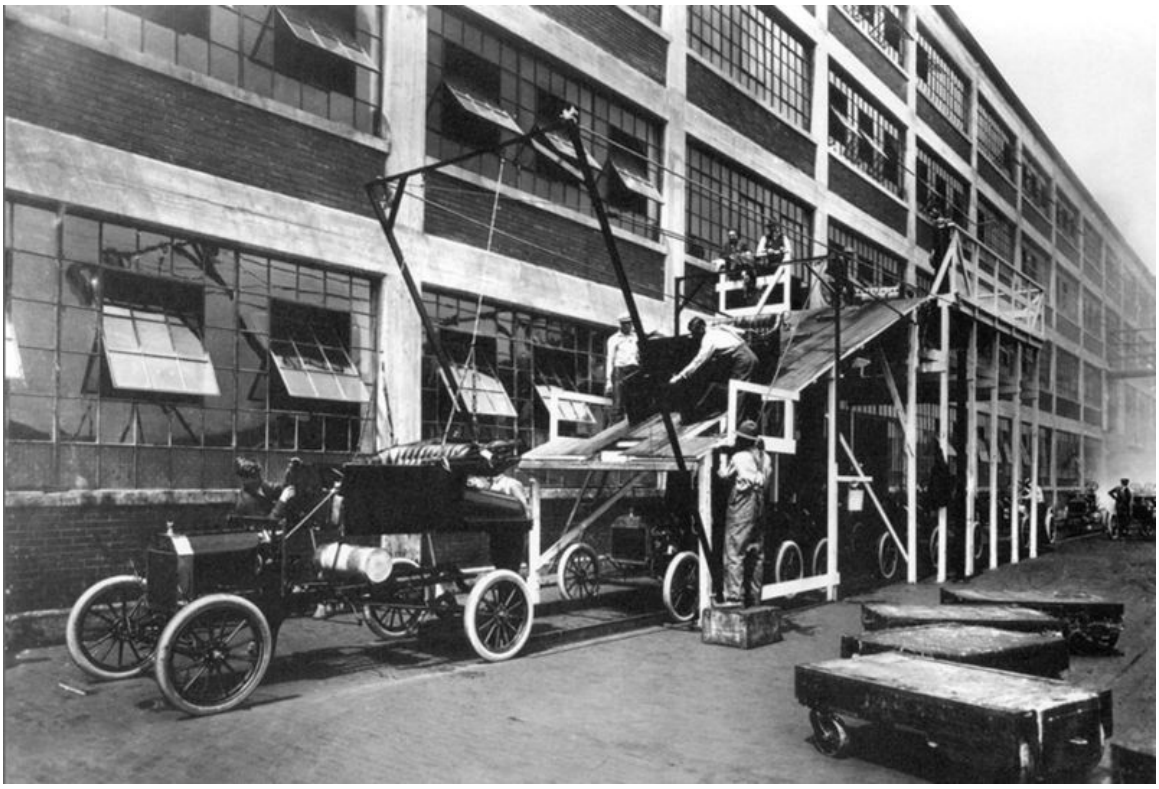
In an assembly line, car assembly is split between several stations, all working simultaneously. When one station is finished with a car, it passes it on to the next. By

having three stations, a total of three different cars can be operated on at the same time, each one at a different stage of its assembly.

After finishing its work on the first car, the engine installation crew can begin working on the second car. While the engine installation crew works on the second car, the first car can be moved to the hood station and fitted with a hood, then to the wheels station and be fitted with wheels. After the engine has been installed on the second car, the second car moves to the hood assembly. At the same time, the third car moves to the engine assembly. When the third car's engine has been mounted, it then can be moved to the hood station; meanwhile, subsequent cars (if any) can be moved to the engine installation station.

Assuming no loss of time when moving a car from one station to another, the longest stage on the assembly line determines the throughput (20 minutes for the engine installation) so a car can be produced every 20 minutes, once the first car taking 35 minutes has been produced.

History



1913 Experimenting with mounting body on Model T chassis. Ford tested various assembly methods to optimize the procedures before permanently installing the equipment. The actual assembly line used an overhead crane to mount the body.

Before the 20th century

Before the 20th century, most manufactured products were made individually by hand. A single craftsman or team of craftsmen would create each part of a product. They would use their skills and tools such as files and knives to create the individual parts. They would then assemble them into the final product, making cut-and-try changes in the parts until they fit and could work together (craft production).

The assembly line concept wasn't "invented" at one time by one person. It has been independently redeveloped throughout history based on logic. Its exponentially larger development at the end of the 19th century and beginning of the 20th occurred among various people over decades, as other aspects of technology allowed. The development of toolpath control via jigs, fixtures, and machine tools (such as the screw-cutting lathe and milling machine) during the 19th century provided the prerequisites for the modern assembly line by making interchangeable parts a practical reality. The transition to other methods began as creativity and logic took advantage of the opportunities that the aforementioned machining developments presented. Thus, before the modern assembly line took shape, there were prototypical forms in various industries, as outlined below.

Early history

The Terracotta Army commissioned by the first Chinese Emperor Qin Shi Huangdi is a collection of about 8000 life-sized ceramic soldiers and horses buried with the emperor. The figures had their separate body parts manufactured by different workshops that were later assembled to completion. Notably, each workshop inscribed its name on the part they manufactured to add traceability for quality construction.

At the peak of its efficiency in the early 16th century, the Venetian Arsenal employed some 16,000 people who apparently were able to produce nearly one ship each day, and could fit out, arm, and provision a newly-built galley with standardized parts on an assembly-line basis not seen again until the Industrial Revolution.

Industrial revolution

The Industrial Revolution in Western Europe and North America, but perhaps most especially in Great Britain and in New England, led to a proliferation of manufacturing and invention. Many industries, notably textiles, firearms, clocks and watches, buttons, horse-drawn vehicles, railroad cars and locomotives, sewing machines, and bicycles, saw expeditious improvement in materials handling, machining, and assembly during the 19th century, although modern concepts such as industrial engineering and logistics had not yet been named.

Adam Smith discusses the division of labour in the manufacture of pins at length in his book *The Wealth of Nations* (published in 1776).

Probably the first linear and continuous assembly process of post-Renaissance times were the Portsmouth Block Mills built between 1801 and 1803. Marc Isambard Brunel (father of Isambard Kingdom Brunel), with the help of Henry Maudslay and others, designed 22 types of machine tools to make the parts for the blocks used by the Royal Navy. This factory was so successful it remained in use until the 1960s, with the workshop still visible at HM Dockyard in Portsmouth, and still containing some of the original machinery.

Eli Whitney is sometimes credited with developing the armory system of manufacturing in 1801, using the ideas of division of labor, engineering tolerance, and interchangeable parts to create assemblies from parts in a repeatable manner. But Whitney's contribution was mostly as a popularizer rather than "the inventor" of repeatability. He was probably inspired by several others (including Honoré Blanc), or at least by the contemporary zeitgeist that was building around such ideas. Thomas Jefferson had tried to bring a French mechanic (almost certainly Blanc) and his methods to America in 1785, but the project never went anywhere. A few years later Whitney and his American contemporaries succeeded in introducing the relevant concepts (interchangeable parts, tool-path control via machine tools and jigs, transfer of skill to the equipment, allowing use of semi-skilled or unskilled machine operators) to American firearm-manufacture.

Conveyor systems

Steam powered conveyor lifts began being used for loading and unloading ships some time in the last quarter of the 19th century. Hounshell (1984) shows a ca. 1885 sketch of an electric powered conveyor moving cans through a filling line in a canning factory.

The meatpacking industry of Chicago is believed to be one of the first industrial assembly lines (or dis-assembly lines) to be utilized in the United States starting in 1867. Workers would stand at fixed stations and a pulley system would bring the meat to each worker and they would complete one task. Henry Ford and others have written about the influence of this slaughterhouse practice on the later developments at Ford Motor Company.

Olds Motor Vehicle Company (1901)

Ransom Olds patented the assembly line concept, which he put to work in his Olds Motor Vehicle Company factory in 1901, becoming the first company in America to mass-produce automobiles. This development is often overshadowed by the independent redevelopment of assembly-line work at Ford Motor Company a few years later, which introduced the ramifications of the method to a wider audience.

Ford Motor Company (1908-1915)

Ford assembly line, 1913. The magneto assembly line was the first.

The assembly line developed for the Ford Model T had immense influence on the world. Despite oversimplistic attempts to attribute it to one man or another, it was in fact a composite development based on logic that took 7 years and plenty of intelligent men. The principal leaders are discussed below.

The basic kernel of an assembly line concept was introduced to Ford Motor Company by William "Pa" Klann upon his return from visiting a Chicago slaughterhouse and viewing what was referred to as the "disassembly line", where animals were butchered as they moved along a conveyor. The efficiency of one person removing the same piece over and over caught his attention. He reported the idea to Peter E. Martin, soon to be head of Ford production, who was doubtful at the time but encouraged him to proceed. Others at Ford have claimed to have put the idea forth to Henry Ford, but Pa Klann's slaughterhouse revelation is well documented in the archives at the Henry Ford Museum and elsewhere, making him an important contributor to the modern automated assembly line concept. The process was an evolution by trial and error of a team consisting primarily of Peter E. Martin, the factory superintendent; Charles E. Sorensen, Martin's assistant; C. Harold Wills, draftsman and toolmaker; Clarence W. Avery; Charles Ebender; and József Galamb. Some of the groundwork for such development had recently been laid by the intelligent layout of machine tool placement that Walter Flanders had been doing at Ford up to 1908.

In 1922 Ford (via his ghostwriter Crowther) said of his 1913 assembly line:

"I believe that this was the first moving line ever installed. The idea came in a general way from the overhead trolley that the Chicago packers use in dressing beef."

Charles E. Sorensen, in his 1956 memoir *My Forty Years with Ford*, presented a different version of development that was not so much about individual “inventors” as a gradual, logical development of industrial engineering:

"What was worked out at Ford was the practice of moving the work from one worker to another until it became a complete unit, then arranging the flow of these units at the right time and the right place to a moving final assembly line from which came a finished product. Regardless of earlier uses of some of these principles, the direct line of succession of mass production and its intensification into automation stems directly from what we worked out at Ford Motor Company between 1908 and 1913. Henry Ford is generally regarded as the father of mass production. He was not. He was the sponsor of it."

As a result of these developments in method, Ford's cars came off the line in three minute intervals. This was much faster than previous methods, increasing production by eight to one (requiring 12.5 man-hours before, 1 hour 33 minutes after), while using less manpower. It was so successful, paint became a bottleneck. Only japan black would dry fast enough, forcing the company to drop the variety of colors available before 1914, until fast-drying Duco lacquer was developed in 1926. In 1914, an assembly line worker could buy a Model T with four months' pay.

The assembly line technique was an integral part of the diffusion of the automobile into American society. Decreased costs of production allowed the cost of the Model T to drop within the budget of the American middle class. In 1908, the price of a Model T was around $825, and by 1912 it had dropped to around $575. This price reduction is comparable to a drop from $15,000 to $10,000 in dollar terms from the year 2000.

Ford's complex safety procedures—especially assigning each worker to a specific location instead of allowing them to roam about—dramatically reduced the rate of injury. The combination of high wages and high efficiency is called "Fordism", and was copied by most major industries. The efficiency gains from the assembly line also coincided with the take-off of the United States. The assembly line forced workers to work at a certain pace with very repetitive motions which led to more output per worker while other countries were using less productive methods.

Ford at one point considered suing other car companies because they used the assembly line in their production, but decided against, realizing it was essential to creation and expansion of the industry as a whole.

In the automotive industry, its success was dominating, and quickly spread worldwide. Ford France and Ford Britain in 1911, Ford Denmark 1923, Ford Germany 1925; in 1921, Citroen was the first native European manufacturer to adopt it. Soon, companies had to have assembly lines, or risk going broke by not being able to compete; by 1930, 250 companies which did not had disappeared.

Sociological problems

Sociological work has explored the social alienation and boredom that many workers feel because of the repetition of doing the same specialized task all day long. Because workers have to stand in the same place for hours and repeat the same motion hundreds of times per day, repetitive stress injuries are a possible pathology of occupational safety. Industrial noise also proved dangerous. When it was not too high, workers were often prohibited from talking. Charles Piaget, a skilled worker at the LIP factory, recalled that beside being prohibited from speaking, the semi-skilled workers had only 25 centimeters in which to move. Industrial ergonomics later tried to minimize physical trauma.

Improved working conditions

In his autobiography Henry Ford (1922) mentions several benefits of the assembly line including:

- Workers do no heavy lifting
- No stooping or bending over
- No special training required
- There are jobs that almost anyone can do
- Provided employment to immigrants

The gains in productivity allowed Ford to increase worker pay from $2.50 per day to $5.00 per day and to reduce the hourly work week while continuously lowering the Model T price. These goals appear altruistic, however, it has been argued that they were implemented by Ford in order to reduce high employee turnover.

Chapter-2

AS-Interface

AS-Interface (Actuator Sensor Interface, AS-i) is an industrial networking solution (physical layer, data access method and protocol) used in PLC, DCS and PC-based automation systems. It is designed for connecting simple field I/O devices (e.g. binary ON/OFF devices such as actuators, sensors, rotary encoders, analog inputs and outputs, push buttons, and valve position sensors) in discrete manufacturing and process applications using a single 2-conductor cable.

AS-Interface is an 'open' technology supported by a multitude of automation equipment vendors. According to AS-Interface International there are currently, over 18 Million AS-i field devices are installed globally, growing at about 2 million per year.

AS-Interface is a networking alternative to the hard wiring of field devices. It can be used as a partner network for higher level fieldbus networks such as *Profibus, *DeviceNet, Interbus and *Industrial Ethernet, for whom it offers a low-cost remote I/O solution. It is used in automation applications, including conveyor control, packaging machines, process control valves, bottling plants, electrical distribution systems, airport carousels, elevators, bottling lines and food production lines.

AS-Interface provides a basis for Functional Safety in machinery safety/emergency stop applications. Safety devices communicating over AS-Interface follow all the normal data rules. The required level of data verification is provided by dynamic changes in the data. This technology is called Safety as Work and allows safety devices and standard, non-safe devices to be connected to the same network. Using appropriate safe input hardware (e.g. light curtains, e-stop buttons, and door interlock switches), AS-Interface can provide safety support up to SIL (Safety Integrity Level) 3 according to IEC 61508, CAT 4 according to EN954-1 as well as Performance Level e (PL e) according to EN ISO 13849-1.

The AS-Interface specification is managed by AS-International, a member funded organization located in Gelenhausen/Germany. Several international daughter organizations exist around the world.

Overview

AS-Interface is a system that requires four basic components:

- Exactly one *network master*, in most cases in the form of a Gateway to a higher level industrial network or a PLC backplane card,
- A number of *network slaves*, in most cases input and output modules,
- Exactly one power supply used to power the *network slaves* and enabling communication with the *network master*, and
- The wiring infrastructure, in most case accomplished using the *yellow flat cable*.

The underlying communication procedure is a Master-Slave method, by which the master initiates data exchange with a slave and requires that slave to respond within in define maximum time, making AS-Interface a deterministic networking solution. Conformance testing by an independent certification lab assures that certified products from all manufacturers will communicate on a given network. AS-Interface data exchanges are based on a *Master-Call*, where the data frame consists of a 5-bit device addresses and 4-bit data packets (e.g. digital output information). The total length of the *Master-Call* 14 bit. The resulting *Slave-Response* is 7 bit long, containing 4 bit of user information (e.g. the values of slaves inputs).

Voltage levels on the network range between 29,5 .. 31,6 V DC and data protection, in addition to the framing bits, is accomplished via Manchester-II coding, a highly symmetrical, floating layout with Alternating Pulse Modulation. The networks bit time is 6 µs. Segment length is limited to 100 meters.. Under certain conditions so-called a Terminator and/or Tuner can be used to extend the allowable segment length to 200m or 300m, respectively.

History

AS-Interface was developed during the late 1980 and early 1990 by a group (consortium) of 11 companies mostly known for their offering of industrial non-contact sensing devices like inductive sensors, photoelectric sensors, capacitive sensors and ultrasonic sensors. Once development was completed the consortium was resolved and a member organization, AS-International, was founded. The first operational system was shown at the 1994 Hannover fair (Hannover Messe).

Original Specification (1994, Version 2.04)

In its original form the network was capable of supporting up to 31 binary I/O devices, where each device could exchange 4 bit of input and 4 bit of output data, resulting in a total of 124 inputs and 124 outputs on a single network. Important features like **Automatic Single Node Replacement** were already part of the system. The network update time is easily calculated by multiplying the number I/O nodes with the deterministic update time for each node (approximately 150 microseconds), for a

maximum update time of 5 ms. This simplified calculation does not include the *Management Phase* which is negligible for typical installations.

Enhancements (1998, Version 2.11)

Following its introduction users quickly adopted AS-Interface, driving the demand for additional functionality and features. As a consequence, these demands were addressed with certain specification enhancements allowing the creation of analog input/output devices and increasing the number of possible binary I/O devices to 62. Diagnostics functionality was also enhanced by the creation of the **Peripheral Fault Bit**. In order to retain full forward and backward compatibility, the size of the data frame exchanged between the network master (Scanners and Gateways) was not increased. Instead, one of the four output bits was used to select between the so-called A and B nodes. This enabled each of the 31 addresses to be used twice. The address space was increased to 1A to 31A plus 1B to 31B. As a consequence of using an output bit as the A/B selector, the fourth output bit was not available to the user and binary I/O nodes built to this profile offered a maximum of 4 inputs and 3 outputs, increasing the total amount of I/O on a single network to 248 inputs and 186 outputs. The maximum update time of a fully loaded network is 10 ms.

Additional capabilities (2005/2007, Version 3.0)

By 2005 it became necessary to address additional user requirements. Also, the increased usage of Ethernet based industrial protocols called for a low level solution that overcame the inherent shortcomings of Ethernet (e.g. restricted topology, large data frame, costly usage of switches ...) This specification addressed the users requirements by defining new communication profiles for binary and analog data plus the introduction of a serial data transmission profile. The following is an incomplete list of the new capabilities

- Binary I/O nodes supporting A/B addressing with 4 Inputs and 4 Outputs
- Binary I/O nodes supporting A/B addressing with 8 Inputs and 8 Outputs
- Configurable (8, 12 or 16 bit) fast analog channel
- Full Duplex bit serial data channel

With these new capabilities, AS-Interface becomes the ideal partner network for any of the currently available Ethernet based industrial protocols. Gateways to EtherNet/IP™, PROFINET, Modbus/TCP, SERCOS III and others are available. Some controls experts have voiced the opinion that within the next 10 years networking solutions positioned between AS-Interface and Ethernet will not be used in any new installation. In a worst case scenario, using 62 nodes with 4 inputs and 4 outputs each the update time is 10 ms for the inputs and 20 ms for the outputs.

Components

An AS-Interface network requires only a few basic components falling into the following general categories:

- Scanners and Gateways (also called masters)
- Power supplies and repeaters
- Modules (also called slaves)
- Network cable, installation hardware and useful tool (infrastructure)

Scanners and Gateways

The Scanner/Gateway performs two functions. With respect to the AS-Interface network it is a master, performing the data exchange with the modules and updating its internal I/O image. The functionality of the master is defined in the Master Profile of the AS-Interface specification. As part of specification version 3.0 the M4 Master Profile has been defined. Any given network can only have one Scanner/Gateway. With respect to a connected PLC/DCS or PC the Scanner/Gateway is a slave. The AS-Interface community typically uses the word Gateway when the AS-Interface master connects to an upper-level network like DeviceNet, Profibus or any of the industrial Ethernet flavors. On the other hand, if it resides on the backplane of a PLC it is usually referred to as a Scanner. Since AS-Interface communication is based on the Master-Slave communication method, any network must have only one master at a time.

Power supply

Any AS-Interface segment must be powered. This is typically accomplished connecting an AS-Interface power supply. These supplies have certain unique characteristics regarding internal circuitry and output voltage. Standard 24VDC power supplies can not be used to directly power a segment. The total length AS-Interface network cable in a single segment must be no more than 100m. If the total network length must be longer repeaters can be used. As the repeater galvanically isolates any two segment a new power supply must be used on *the far side* of the repeater. A common misconception exists concerning the number of repeaters in a network. It has been stated that the maximum length of an AS-Interface network can be 300m, created by using two repeaters. This is not the case at all! What matters is not how many repeaters are using but rather how many repeaters any data packet, originating at a Scanner or Gateway, has to cross before reaching the I/O node. Due to the tight timing constraints defined each packet can at most travel across two repeaters before reaching an AS-Interface node. This has the following consequences:

1. Linear networks with the Scanner/Gateway mounted at one end can be 300m long
2. Linear network with 600m length can be constructed when the Scanner/Gateway is mounted in the middle segment
3. Star shaped networks with virtually no length limitation are possible

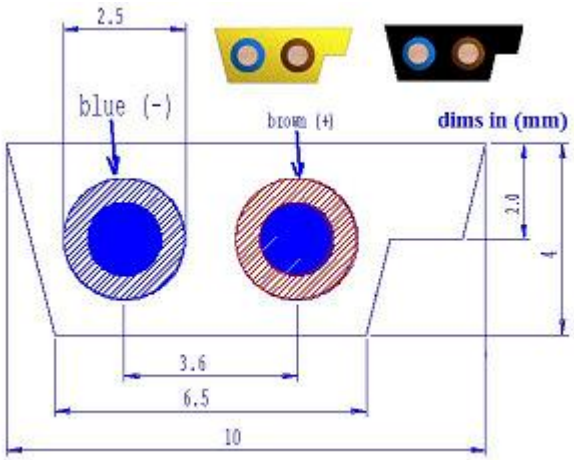
Modules

This is by far the largest group of components and includes binary and analog I/O modules, stack lights, pushbuttons, sensors with integrated ASIC, valve control boxes, E-stops, light curtains; in general any device that can exchange data with the PLC. Each

module on the network must have a unique address. For AS-Interface the address space ranges from 0 to 31, where 0 cannot be used, but is reserved for Automatic Single Node Replacement. Since adoption of specification 2.11 this address space is further divided into A and B extended addresses. As a result, using a module designed to support this addressing mode, it possible to have two modules at each address; one at the A *half* and one at the B *half*. (Ex. 1A and 1B, 17A and 17B)
The current specification Version 3.0 has adds many the ability to construct many new types of I/O combinations, including binary modules with 4 inputs and 4 outputs supporting A/B addressing.

Network cable

The vast majority of AS-Interface installations utilize the AS-Interface flat cable, defined as part of the AS-Interface specifications. A relatively small number of industries (e.g. valve control in process automation) use a round cable, mostly because it is easier to pull through conduit. While the shape of the cable does not matter (any other cable can be used) the electrical characteristics of the selected cable matters greatly. To prevent problems due to improper cable, most professional suggest the AS-Interface flat cable. This cable is designed to make use of a cable piercing technology. When an AS-Interface module is installed on the network, piercing needles penetrate the cable jacket and displace the internal copper strands without cutting them. This allows AS-Interface modules to be installed anywhere on the network without cutting and preparing (i.e. removing cable jacket, stripping insulation and possibly applying a ferule) the cable first. The result is a faster installation without the chance of inadvertent shorts between the leads.



Here is a flat cable drawing

There are several types of cables available. Yellow cable is usually used to power AS-Interface modules and enable communication between the field devices and the scanner or Gateway. This cable is offered in several jacket materials to address specific applications needs. The AS-Interface black cable is typically used to supply modules with 24VDC AUX power. No communication takes place on this cable. Similar to the yellow

cable, the black cable is also produced using various jacket material to address the specific needs of the application. A red jacketed cable has been defined but is virtually unused. Its intended use was in applications where AC power is supplied to the field nodes. The two leads inside the AS-Interface cable are brown (+ lead) and blue (- lead) independent of material makeup and outer jacket color.

Designing a Network

An AS-Interface network is a collection of network segments. There are very few rule that need to be satisfied when designing an AS-Interface network:

1. There can be no duplicate addressed on a network
2. Each segment must be 100m or less in total cable length
3. Each network must power exactly one master
4. Each segment must have power exactly one AS-Interface power supply
5. When repeaters are used, a slave can not be more than "two repeater transitions" from the master
6. The shape (i.e. topology) of a segment is arbitrary (unrestricted)

Using these basic rules it should be clear that

- A linear network, with the master at one end of the network, can be 300m long
- A linear network, with the master "in the middle" of the network, can be 500m long

In some applications longer networks are desirable (e.g. Process Automation applications). This is possible through the installation of Terminator and Tuners. are used.

Terminator and Tuner

Terminators are fixed value devices that must be added at the physical end of a network and are designed to reduce signal reflections. In most cases Terminators will only work reliably if the segment is essentially linear. This is significant limitation as most AS-Interface networks make extensive use of the fact that any arbitrary network. topology can be used. A Tuner is used in much the same way as a Terminator (again segments have to be linear) but differs in its electrical characteristic. A Tuner is must, after connecting it to the segment, must be activated (or tuned). During this process the Tuner actively varies the values of it internal termination components and determines the optimal settings for the segment, i.e. those that minimize the number of network errors. Even though this optimization process is the strength of the Tuner and the sole reason for its ability to allow even longer networks, it is also its greatest disadvantage. While a Terminator allows the addition (or subtraction) of modules without additional work, a Tuner must be 're-tuned' whenever the network is changed (i.e. removing/adding modules and adding/removing network cable.) When using Terminators and Tuners in conjunction

with repeaters, the signal propagation time along the wire and across repeaters must be considered. Higher speed repeaters have been developed to address this issue.

Other components

Passive taps, flat-to-round cable adapters, handheld addressing tools and many other accessories are designed to further assist in the installation of AS-Interface networks.

Chapter-3

Cellular Manufacturing and Capacity Planning

Cellular manufacturing

Cellular Manufacturing is a model for workplace design, and has become an integral part of lean manufacturing systems. Cellular Manufacturing is based upon the principals of Group Technology, which seeks to take full advantage of the similarity between parts, through standardisation and common processing. In Functional Manufacturing similar machines are placed close together (e.g. lathes, millers, drills etc). Functional layouts are more robust to machine breakdowns, have common jigs and fixtures in the same area and supports high levels of demarcation. In Cellular Manufacturing systems machines are grouped together according to the families of parts produced. The major advantage is that material flow is significantly improved, which reduces the distance travelled by materials, inventory and cumulative lead times. Cellular Manufacturing is most suitable for batch manufacturing.

The goal of lean manufacturing is the aggressive minimisation of waste, called *muda*, to achieve maximum efficiency of resources. Cellular manufacturing, sometimes called cellular or cell production, arranges factory floor labor into semi-autonomous and multi-skilled teams, or work cells, who manufacture complete products or complex components. Properly trained and implemented cells are more flexible and responsive than the traditional mass-production line, and can manage processes, defects, scheduling, equipment maintenance, and other manufacturing issues more efficiently.

History

Cellular Manufacturing is the application of the principles of Group Technology in manufacturing. Group Technology was proposed by Flanders in 1925 and adopted in Russia by Mitrofanov in 1933 (although the work was translated into English in 1966). Jack Burbidge (1978) did much to promote Group Technology in the UK. Although there appear to have been similar applications earlier in history Portsmouth Block Mills offers what by definition constitutes an early example of cellular manufacturing. By 1808, using machinery designed by Marc Isambard Brunel and constructed by Henry Maudslay, the

Block Mills were producing 130,000 blocks (pulleys) for the Royal Navy per year in single unit lots, with 10 men operating 42 machines arranged in three production flow lines. This installation apparently reduced manpower requirements by 90% (from 110 to 10), reduced cost substantially and greatly improved block consistency and quality. Group Technology is a management strategy with long term goals of staying in business, growing, and making profits. Companies are under relentless pressure to reduce costs while meeting the high quality expectations of the customer to maintain a competitive advantage. Successfully implementing Cellular manufacturing allows companies to achieve cost savings and quality improvements, especially when combined with the other aspects of lean manufacturing. Cell manufacturing systems are currently used to manufacture anything from hydraulic and engine pumps used in aircraft to plastic packaging components made using injection molding.

Design

The goal of cellular manufacturing is having the flexibility to produce a high variety of low demand products, while maintaining the high productivity of large scale production. Cell designers achieve this through modularity in both process design and product design.

Process Design

The division of the entire production process into discrete segments, and the assignment of each segment to a work cell, introduces the modularity of processes. If any segment of the process needs to be changed, only the particular cell would be affected, not the entire production line. For example, if a particular component was prone to defects, and this could be solved by upgrading the equipment, a new work cell could be designed and prepared while the obsolete cell continued production. Once the new cell is tested and ready for production, the incoming parts to and outgoing parts from the old cell will simply be rerouted to the new cell without having to disrupt the entire production line. In this way, work cells enable the flexibility to upgrade processes and make variations to products to better suit customer demands while largely reducing or eliminating the costs of stoppages. While the machinery may be functionally dissimilar, the family of parts produced contains similar processing requirements or has geometric similarities. Thus, all parts basically follow the same routing with some minor variations (e.g., skipping an operation). The cells may have no conveyorized movement of parts between machines, or they may have a flow line connected by a conveyor that can provide automatic transfer.

Product Design

Product modularity must match the modularity of processes. Even though the entire production system becomes more flexible, each individual cell is still optimised for a relatively narrow range of tasks, in order to take advantage of the mass-production efficiencies of specialisation and scale. To the extent that a large variety of products can be designed to be assembled from a small number of modular parts, both high product variety and high productivity can be achieved. For example, a varied range of automobiles may be designed to use the same chassis, a small number of engine

configurations, and a moderate variety of car bodies, each available in a range of colors. In this way, a large variety of automobiles, with different performances and appearances and functions, can be produced by combining the outputs from a more limited number of work cells.

In combination, each modular part is designed for a particular work cell, or dedicated clusters of machines or manufacturing processes. Cells are usually bigger than typical conventional workstations, but smaller than a complete conventional department. After conversion, a cellular manufacturing layout usually requires less floor space as a result of the optimized production processes. Each cell is responsible for its own internal control of quality, scheduling, ordering, and record keeping. The idea is to place the responsibility of these tasks on those who are most familiar with the situation and most able to quickly fix any problems. The middle management no longer has to monitor the outputs and interrelationships of every single worker, and instead only has to monitor a smaller number of work cells and the flow of materials between them, often achieved using a system of *kanbans*.

Implementation

The biggest challenge when implementing cellular manufacturing in a company is dividing the entire manufacturing system into cells. The issues may be conceptually divided in the "hard" issues of equipment, such as material flow and layout, and the "soft" issues of management, such as upskilling and corporate culture.

The hard issues are a matter of design and investment. The entire factory floor is rearranged, and equipment is modified or replaced to enable cell manufacturing. The costs of work stoppages during implementation can be considerable, and lean manufacturing literature recommend that implementation should be phased to minimize the impacts of such disruptions as much as possible. The rearrangement of equipment (which is sometimes bolted to the floor or built into the factory building) or the replacement of equipment that is not flexible or reliable enough for cell manufacturing also pose considerable costs, although it may be justified as the upgrading obsolete equipment. In both cases, the costs have to be justified by the cost savings that can be realistically expected from the more flexible cell manufacturing system being introduced, and miscalculations can be disastrous. A common oversight is the need for multiple jigs, fixtures and or tooling for each cell. Properly designed, these requirements can be accommodated in specific-task cells serving other cells; such as a common punch press or test station. Too often, however, the issue is discovered late and each cell is found to require its own set of tooling.

The soft issues are more difficult to calculate and control. The implementation of cell manufacturing often involves employee training and the redefinition and reassignment of jobs. Each of the workers in each cell should ideally be able to complete the entire range of tasks required from that cell, and often this means being more multi-skilled than they were previously. For this reason, transition from a progressive assembly line type of manufacturing to cellular is often best managed in stages with both types co-existing for a

period of time. In addition, cells are expected to be self-managing (to some extent), and therefore workers will have to learn the tools and strategies for effective teamwork and management, tasks that workers in conventional factory environments are entirely unused to. At the other end of the spectrum, the management will also find their jobs redefined, as they must take a more "hands-off" approach to allow work cells to effectively self-manage. Instead, they must learn to perform a more oversight and support role, maintaining a system where work cells self-optimize through supplier-input-process-output-customer (SIPOC) relationships. These soft issues, while difficult to pin down, pose a considerable challenge for cell manufacturing implementation; a factory with a cell manufacturing layout but without cell manufacturing workers and managers is unlikely to achieve the cell manufacturing benefits.

Product start-ups can be more difficult to manage if assembly training was traditionally accomplished station-by-station on a fixed assembly line. As each operator in a cell is responsible for a larger number of assembled parts and operations, the time needed to master the sequence and techniques is considerably longer. If multiple parallel cells are used, each cell must be launched separately (meaning slower production ramp) or with equal training resources (meaning more in total). The consideration of the cell's internal group dynamics, personalities and other traits is often more of a concern in cellular manufacturing due to the closer proximity and co-dependency of the team members; however properly implemented this is a major benefit of cellular manufacturing.

Benefits and Costs

There are many benefits of cellular manufacturing for a company if applied correctly. Most immediately, processes become more balanced and productivity increases because the manufacturing floor has been reorganized and tidied up.

Part movement, set-up time, and wait time between operations are reduced, resulting in a reduction of work in progress inventory freeing idle capital that can be better utilized elsewhere. Cellular manufacturing, in combination with the other lean manufacturing and just-in-time processes, also helps eliminate overproduction by only producing items when they are needed. The results are cost savings and the better control of operations.

There are some costs of implementing cellular manufacturing, however, in addition to the set-up costs of equipment and stoppages noted above. Sometimes different work cells can require the same machines and tools, possibly resulting in duplication causing a higher investment of equipment and lowered machine utilization. However, this is a matter of optimization and can be addressed through process design.

Capacity planning

Capacity planning is the process of determining the production capacity needed by an organization to meet changing demands for its products. In the context of capacity planning, "capacity" is the maximum amount of work that an organization is capable of

completing in a given period of time. The phrase is also used in business computing as a synonym for Capacity Management

A discrepancy between the capacity of an organization and the demands of its customers results in inefficiency, either in under-utilized resources or unfulfilled customers. The goal of capacity planning is to minimize this discrepancy. Demand for an organization's capacity varies based on changes in production output, such as increasing or decreasing the production quantity of an existing product, or producing new products. Better utilization of existing capacity can be accomplished through improvements in overall equipment effectiveness (OEE). Capacity can be increased through introducing new techniques, equipment and materials, increasing the number of workers or machines, increasing the number of shifts, or acquiring additional production facilities.

Capacity is calculated: (number of machines or workers) × (number of shifts) × (utilization) × (efficiency).

The broad classes of capacity planning are lead strategy, lag strategy, and match strategy.

- **Lead strategy** is adding capacity in anticipation of an increase in demand. Lead strategy is an aggressive strategy with the goal of luring customers away from the company's competitors. The possible disadvantage to this strategy is that it often results in excess inventory, which is costly and often wasteful.
- **Lag strategy** refers to adding capacity only after the organization is running at full capacity or beyond due to increase in demand (North Carolina State University, 2006). This is a more conservative strategy. It decreases the risk of waste, but it may result in the loss of possible customers.
- **Match strategy** is adding capacity in small amounts in response to changing demand in the market. This is a more moderate strategy.

In the context of systems engineering, capacity planning is used during system design and system performance monitoring.

Capacity planning is long-term decision that establishes a firms' overall level of resources. It extends over time horizon long enough to obtain resources. Capacity decisions affect the production lead time, customer responsiveness, operating cost and company ability to compete. Inadequate capacity planning can lead to the loss of the customer and business. Excess capacity can drain the company's resources and prevent investments into more lucrative ventures. The question of when capacity should be increased and by how much are the critical decisions.

Capacity – Available or Required?

From a scheduling perspective it is very easy to determine how much capacity (or time) will be required to manufacture a quantity of parts. Simply multiply the Standard Cycle Time by the Number of Parts and divide by the part or process OEE %.

If production is scheduled to produce 500 pieces of product A on a machine having a cycle time of 30 seconds and the OEE for the process is 85%, then the time to produce the parts would be calculated as follows:

(500 Parts X 30 Seconds) / 85% = 17647.1 seconds The OEE index makes it easy to determine whether we have ample capacity to run the required production. In this example 4.2 hours at standard versus 4.9 hours based on the OEE index.

Repeating this process for all the parts that run through a given machine, it is possible to determine the total capacity required to run production.

Capacity Available

If you are considering new work for a piece of equipment or machinery, knowing how much capacity is available to run the work will eventually become part of the overall process. Typically, an annual forecast is used to determine how many hours per year are required. It is also possible that seasonal influences exist within your machine requirements, so perhaps a quarterly or even monthly capacity report is required.

To calculate the total capacity available, we can use the formula from our earlier example and simply adjust or change the volume accordingly based on the period being considered. The available capacity is difference between the required capacity and planned operating capacity.

Chapter-4

Business Process Improvement

Business process improvement (BPI) is a systematic approach to help an organization optimize its underlying processes to achieve more efficient results.

Overview

The organization may be a for-profit business, a non-profit organization, a government agency, or any other ongoing concern. Most BPI techniques were developed and refined in the manufacturing era, though many of the methodologies (like Six Sigma) have been successfully adapted to work in the predominantly service-based economy of today. While there are differences in the challenges that each type of industry poses, the fact remains that the core principles of BPI and how they apply to business improvement remain portable across industries and functions.

It should be noted that BPI focuses on "doing things right" more than it does on "doing the right thing". In essence, BPI attempts to reduce variation and/or waste in processes, so that the desired outcome can be achieved with better utilisation of resources.

BPI works by:

- Defining the organization's strategic goals and purposes *(Who are we, what do we do, and why do we do it?)*
- Determining the organization's customers (or stakeholders) *(Who do we serve?)*
- Aligning the business processes to realize the organization's goals *(How do we do it better?)*

The goal of BPI is a radical change in the performance of an organization, rather than a series of incremental changes (compare TQM). Michael Hammer and James Champy popularized this radical model in their book ‘’Reengineering the Corporation: A Manifesto for Business Revolution’’ (1993). Hammer and Champy stated that the process was not meant to impose trivial changes, such as 10 percent improvements or 20 percent cost reductions, but was meant to be revolutionary.

Many businesses in the 1990s used the phrase "reengineering" as a euphemism for layoffs. Other organizations did not make radical changes in their business processes and did not make significant gains, and, therefore, wrote the process off as a failure. Yet, others have found that BPI is a valuable tool in a process of gradual change to a business.

Roles

There are four roles within a business Management system: Business Leader, Process Owner, Operational Manager, and Process Operator. The responsibilities of each of these roles are unique, but work together as a system. Some employees in an organization may perform as many as all four of these roles over the course of a day, week, month, or year.

Business leaders

Business leaders are responsible for creating the business plans (including strategic plans created during the strategic planning process) and associated resourcing plans necessary to cause the organization to be successful.

Senior leaders (corporate) are responsible to define the customer and business objectives the organization needs to achieve in order to be successful. This process includes overseeing the development of the organization’s mission, vision, and values.

Lower leader levels (business unit and functional) are responsible for translating senior leaders' business objectives into business objectives that make sense for their level and that support the accomplishment of the senior leaders' business objectives.

The responsibilities of the business leaders follow the PDCA (plan, do, check, and act) cycle.

Plan: The business leaders create and own the business performance objectives of the organization. Senior leaders need to first understand the requirements of their customers, stockholders, workforce, suppliers, and communities. They need to understand their competition. They need to understand the environmental, economic, technological, social, legal, and political environments that they do business within. Senior leaders need to consider all of these elements as they design a Business model and business Strategy map that will meet the customer and business requirements. Business Leaders then translate these requirements and business environment issues into business performance objectives. Business Leaders then create business plans and associated resourcing plans that will cause the organization to achieve these business objectives. The Business Leaders establish business performance metrics to measure the business’s capability to meet these business objectives. Many organizations create a Balanced scorecard to organize and communicate business performance metrics.

Do: The Business Leaders are responsible to communicate to the organization their business plans. As the organization conducts business, the Business Leaders are responsible to build bridges and remove barriers that will allow the business performance

objectives to be met. The business performance metric data is produced and collected as business is performed by the organization.

Check: The Business Leaders periodically analyze the business performance data and use it to visualize the business's capability to meet business objectives over time (performance trends), compare actual performance against performance targets, and identify performance issues.

Act: The Business Leaders are responsible to create improvement actions to address the performance issues that are identified during their analysis of the business performance data. These improvement actions are created to ensure the organization is able to achieve their business plans.

Process owner

The process owner is the person who is responsible to design the processes necessary to achieve the objectives of the business plans that are created by the Business Leaders. The process owner is responsible for the creation, update and approval of documents (procedures, work instructions/protocols) to support the process. Many process owners are supported by a process improvement team. The process owner uses this team as a mechanism to help create a high performance process. The process owner is the only person who has authority to make changes in the process and manages the entire process improvement cycle to ensure performance effectiveness. This person is the contact person for all information related to the process.

The responsibilities of the process owner follow the PDCA (plan, do, check, and act) cycle.

Plan: The process owners create and own the process performance objectives of the organization. The process owner first needs to understand the external and internal customer requirements for the process. This person uses the business plans as a source to help understand the long term and short term customer and business requirements. This person then translates these requirements into process performance objectives and establishes product (includes service) specifications. This person establishes process performance metrics to measure the process's capability to meet the product specifications and overall process objectives. The set of metrics that are to be reviewed by operational managers and process operators are called key performance indicators (KPIs). The process owner then designs process steps to describe work that when performed will have the capability to produce product that meets the customer and business requirements.

Do: The process owner is responsible to communicate to the operational managers the details of the processes that the operational managers are responsible to execute. As the operational managers and process operators perform the processes, the process owner is responsible to build bridges and remove barriers that will allow the process performance objectives to be met. The process performance metric data is produced and collected as

the process is performed by process operators. The process owner is continually involved with the operational managers and process operators as they use kaizen to continually improve the process as they are performing the work.

Check: The Process Owner periodically analyzes the process performance data and use it to visualize the process's capability to operate within control limits over time (performance trends), compare actual performance against performance targets, and identify performance issues.

Act: The Process Owner is responsible to create improvement actions to address the performance issues that are identified during their analysis of the process performance data. Improvement actions may include the initiation of Lean projects to reduce waste from the process or include the initiation of Six Sigma projects to reduce variation in the process. Improvement actions may include the use of problem solving tools that would include risk assessment and root-cause analysis. Risk assessment is used to identify and reduce, eliminate, or mitigate risk within the process. This is the proactive approach to avoid problems being created from the process. Root-cause analysis is the reactive way to respond to problems that occur from the process. Root-cause analysis is used to identify the causes of problems within the process and identify and implement improvement actions that will ensure these problems do not occur again.

Operational manager

The operational Manager is responsible to bring the resources and processes together to achieve the objectives of the business plans that are created by the business leaders.

The responsibilities of the operational manager follow the PDCA (plan, do, check, and act) cycle.

Plan: The operational managers - in collaboration with each Process Operator, create Process Operator performance objectives for the employees they supervise. The Operational Manager needs to understand the performance requirements of the process. They match employees (Process Operators) with the competency and skill requirements of the process to be performed. They ensure that the Process Operators have the budget, facilities, and technology available to them that is necessary to achieve the performance objectives of the processes.

Do: The operational manager is responsible to teach process operators how to perform the processes (work). Process Operator instruction usually consists of classroom and on-the-job training. The Operational Manager oversees the work and ensures Process Operators receive ongoing informal feedback as to their performance. As the Process Operators perform the processes, the Operational Managers are responsible to build bridges and remove barriers that will allow the process and Process Operator performance objectives to be met. Process and Process Operator performance metric data is produced and collected as the process is performed. The Operational Manager ensures

that Process Operators are using Kaizen to continually improve the process as they are performing the work.

Check: The operational manager periodically analyzes the key performance indicators (KPIs) during the production cycle to evaluate the work group's ability to achieve the process and process operator performance objectives. This data is used to visualize the process and process operator capability to meet business plan objectives over time (performance trends), compare actual performance against performance targets, and identify performance issues. They review this performance data and sort out process operator performance issues from process performance issues. Many organizations use a war room concept to post performance data. Within the war room, the operational manager conducts periodic review and analysis of this performance data.

Act: The operational manager is responsible to create improvement actions to address the performance issues that are identified during their analysis of the process and Process Operator performance data. They address Process Operator performance with ongoing feedback to the Process Operator and/or by using an employee performance management review process. They communicate process performance issues to the Process Operator(s) and the Process Owner.

Process operator

The process operator is responsible to learn and perform the processes (work) necessary to achieve the objectives of the business plans that are created by Business Leaders.

The responsibilities of the process operator follow the PDCA (plan, do, check, and act) cycle.

Plan: The process operators - in collaboration with their Operational Manager, create and own their performance objectives. Process Operators are responsible to understand the performance objectives of the process they are to perform and the specifications of the product they are to produce.

Do: Process operators are responsible to learn the processes (work) that they are to perform. They ensure the processes are performed to meet the process performance objectives and produce product that meets specification. As the Process Operators perform the processes, they are responsible to communicate to their Operational Manager (supervisor) the bridges that need to be built and the barriers that need to be removed to allow the process and Process Operator performance objectives to be met. Process and Process Operator performance metric data is produced and collected as the process is performed.

Check: The process operator periodically reviews the Key performance indicators (KPI's). The Process Operator makes adjustments to their work based on their actual performance compared to KPI targets. The Process Operator is responsible for identifying and reporting any performance issues and stopping production if necessary.

Act: Process operators practice kaizen to continually challenge the process and communicate improvement suggestions to their operational manager (supervisor).

BPI: Key considerations

Processes need to align to business goals An organization's strategic goals should provide the key direction for any Business Process Improvement exercise. This alignment can be brought about by integrating programs like Balanced Scorecard to the BPI initiative. e.g. When deploying Six Sigma, identification of projects can be done on the basis of how they fit into the Balanced Scorecard agenda of the organization.

Customer focus Fast-changing customer needs underscore the importance of aligning business processes to achieve higher customer satisfication. It is imperative in any BPI exercise that the "Voice of Customer" be known, and factored in, when reviewing or redesigning any process.

Importance of benchmarks BPI tools place a lot of emphasis on "measurable results". Accordingly, benchmarks assume an important role in any BPI initiative. Depending on the lifecycle of the process in question, benchmarks may be internal (within the organization), external (from other competing / noncompeting organizations) or dictated by the senior management of the organization as an aspirational target.

Establish process owners For any process to be controllable, it is essential that there be clarity on who is the *process owners*, and what constitutes success/failure of the process. These success/failure levels also help establish "control limits" for the process, and provide a healthy check on whether or not a process is meeting the desired customer objectives.

Methodology of BPI

- Carrying out BPI is a project, so all principles of project management apply. This ensures, for example, that improvement processes do not conflict with each other (such issues would be addressed as part of risk planning).
- The first step in BPI is to define the existing structure and process at play (*AS-IS*).
- Then, the BPI process owners should determine what outcomes would add value to the organization's objectives and how best to align its processes to achieve those outcomes (*TO-BE*).
- Once the outcomes are determined, the organization's work force needs to be re-organized to meet the new objectives, using the variety of tools available within the BPI methodology.

Rummler-Brache methodology

Geary Rummler and Alan Brache defined a comprehensive approach to organizing companies around processes, managing and measuring processes and redefining processes in their 1990 book, Improving Performance. This is probably the best known, systematic approach to business process change and ideas first introduced in this book have been very influential on other, less comprehensive approaches. This book draws heavily from the basic approach laid out in Improving Processes.

Implementing BPI

Most resistance to BPI comes from within an organization. Managers often do not wish to change existing structures. The labor force may resist BPI because of fears of layoffs; however, an organization using BPI on a regular basis, argue many proponents, will already have the proper work force to meet existing business challenges.

Some organizations have implemented BPI on a smaller scale and reported success, by doing the following:

- Start with a small process that can be completed in a short time frame.
- Set clear timelines.
- Do not spread resources thinly and focus on the short term payoff.
- Management and primary stakeholders must be involved, or else even a limited implementation will fail.

Chapter-5

Critical Chain Project Management and Asphalt Plant

Critical chain project management

Critical Chain Project Management (CCPM) is a method of planning and managing projects that puts the main emphasis on the resources required to execute project tasks. It was developed by Eliyahu M. Goldratt. This is in contrast to the more traditional Critical Path and PERT methods, which emphasize task order and rigid scheduling. A Critical Chain project network will tend to keep the resources levelly loaded, but will require them to be flexible in their start times and to quickly switch between tasks and task chains to keep the whole project on schedule.

Origins

Critical Chain Project Management is based on methods and algorithms derived from Theory of Constraints. The idea of CCPM was introduced in 1997 in Eliyahu M. Goldratt's book, *Critical Chain*. Application of CCPM has been credited with achieving projects 10% to 50% faster and/or cheaper than the traditional methods (i.e. CPM, PERT, Gantt, etc.) developed from 1910 to 1950's.

From numerous studies by Standish Group and others[ref] as of 1998 for traditional project management methods, only 44% of projects typically finish on time, projects usually complete at 222% of the duration originally planned, 189% of the original budgeted cost, 70% of projects fall short of their planned scope (technical content delivered), and 30% are cancelled before completion.

These traditional statistics are mostly avoided through CCPM. Typically, CCPM case studies report 95% on-time and on-budget completion when CCPM is applied correctly. Mabin and Balderstone, in their meta-analysis of seventy-eight published case studies, found that implementing Critical Chain resulted in mean reduction in lead-times of 69%, mean reduction of cycle-times of 66%, mean improvement in due date performance of 60%, mean reduction in inventory levels of 50% and mean increases in revenue / throughput of 68%.

Details

With traditional project management methods, 30% of the lost time and resources are typically consumed by wasteful techniques such as bad multi-tasking, Student syndrome, In-box delays, and lack of prioritization.{}

In project management, the **critical chain** is the sequence of both precedence- and resource-dependent terminal elements that prevents a project from being completed in a shorter time, given finite resources. If resources are always available in unlimited quantities, then a project's critical chain is identical to its critical path.

Critical chain is used as an alternative to critical path analysis. The main features that distinguish the critical chain from the critical path are:

1. *The use of (often implicit) resource dependencies*. Implicit means that they are not included in the project network but have to be identified by looking at the resource requirements.
2. *Lack of search for an optimum solution*. This means that a "good enough" solution is enough because:
    1. As far as is known, there is no analytical method of finding an absolute optimum (*i.e.* having the overall shortest critical chain).
    2. The inherent uncertainty in estimates is much greater than the difference between the optimum and near-optimum ("good enough" solutions).
3. *The identification and insertion of buffers*:
    - project buffer
    - feeding buffers
    - resource buffers. (Most of the time it is observed that companies are reluctant to give more resources)
4. Monitoring project progress and health by monitoring the consumption rate of the buffers rather than individual task performance to schedule.

CCPM planning aggregates the large amounts of safety time added to tasks within a project into the buffers in order to protect due-date performance, and to avoid wasting this safety time through bad multitasking, student syndrome, Parkinson's Law and poorly synchronized integration.

Critical chain project management uses buffer management instead of earned value management to assess the performance of a project. Some project managers feel that the earned value management technique is misleading, because it does not distinguish progress on the project constraint (*i.e.* on the critical chain) from progress on non-constraints (*i.e.* on other paths). Event chain methodology can be used to determine a size of project, feeding, and resource buffers.

Method

Planning

A project plan is created in much the same fashion as with critical path. The plan is worked backward from a completion date with each task starting as late as possible.

A duration is assigned to each task. Some software implementations add a second duration: one a "best guess," or 50% probability duration, and a second "safe" duration, which should have higher probability of completion (perhaps 90% or 95%, depending on the amount of risk that the organization can accept). Other software implementations go through the duration estimate of every task and remove a fixed percentage to be aggregated into the buffers.

Resources are assigned to each task, and the plan is resource leveled, using the aggressive durations. The longest sequence of resource-leveled tasks that lead from beginning to end of the project is then identified as the critical chain. The justification for using the 50% estimates is that half of the tasks will finish early and half will finish late, so that the variance over the course of the project should be zero.

Recognizing that tasks are more likely to take more rather than less time due to Parkinson's law, Student syndrome, or other reasons, "buffers" are used to monitor project schedule and financial performance. The "extra" duration of each task on the critical chain—the difference between the "safe" durations and the 50% durations—is gathered together in a buffer at the end of the project. In the same way, buffers are gathered at the end of each sequence of tasks that feed into the critical chain. It is the date at the end of the project buffer that is communicated to external stakedholders as the delivery date.

Finally, a baseline is established, which enables financial monitoring of the project.

An alternate duration-estimation methodology uses probability-based quantification of duration using Monte Carlo simulation. In 1999, a researcher applied simulation to assess the impact of risks associated with each component of project work breakdown structure on project duration, cost and performance. Using Monte Carlo simulation, the project manager can apply different probabilities for various risk factors that affect a project component. The probability of occurrence can vary from 0% to 100% chance of occurrence. The impact of risk is entered into the simulation model along with the probability of occurrence. The Monte Carlo simulation runs over 10,000 iterations and provides a density graph illustrating the overall probability of risk impact on project outcome.

Execution

When the plan is complete and the project ready to kick off, the project network is fixed and the buffers size is "locked" (i.e. their planned duration may not be altered during the project), because they are used to monitor project schedule and financial performance.

With no slack in the duration of individual tasks, the resources are encouraged to focus on the task at hand to complete it and hand it off to the next person or group. The object here is to eliminate bad multitasking, and this is done by providing priority information to all resources. An analogy is drawn in the literature with a relay race. Each element on the project is encouraged to move as quickly as they can: when they are running their "leg" of the project, they should be focused on completing the assigned task as quickly as possible, with no distractions or multitasking. In some case studies, actual batons are reportedly hung by the desks of people when they are working on critical chain tasks so that others know not to interrupt. The goal, here, is to overcome the tendency to delay work or to do extra work when there seems to be time. The CCPM literature contrasts this with "traditional" project management that monitors task start and completion dates. CCPM encourages people to move as quickly as possible, regardless of dates.

Because task durations have been planned at the 50% probability duration, there is pressure on the resources to complete critical chain tasks as quickly as possible, overcoming student's syndrome and Parkinson's Law.

Monitoring

Monitoring is, in some ways, the greatest advantage of the Critical Chain method. Because individual tasks will vary in duration from the 50% estimate, there is no point in trying to force every task to complete "on time;" estimates can never be perfect. Instead, we monitor the buffers that were created during the planning stage. A fever chart or similar graph can be easily created and posted to show the consumption of buffer as a function of project completion. If the rate of buffer consumption is low, the project is on target. If the rate of consumption is such that there is likely to be little or no buffer at the end of the project, then corrective actions or recovery plans must be developed to recover the loss. When the buffer consumption rate exceeds some critical value (roughly: the rate where all of the buffer may be expected to be consumed *before* the end of the project, resulting in late completion), then those alternative plans need to be implemented.

Asphalt plant

An **asphalt plant** is a plant used for the manufacture of asphalt, macadam and other forms of coated roadstone, sometimes collectively known as blacktop.

The manufacture of coated roadstone demands the combination of a number of aggregates, sand and a filler (such as stone dust), in the correct proportions, heated, and finally coated with a binder, usually bitumen based or, in some cases, tar. The

temperature of the finished product must be sufficient to be workable after transport to the final destination. A temperature in the range of 100 - 200 degrees Celsius is normal.

Increasingly, recycled asphalt pavement (RAP) is used as part of the mix. The binder used is flammable, and the heaters are large liquid or gas fired burners. RAP is introduced after the heating process and must be accounted for in the overall mix temperature calcualtions.

There are three main classes of plant: batch heater, semi-continuous (or "asphalt plant"), and continuous (or "drum mix"). The batch heater has the lowest throughput, the continuous plant the highest at up to around 500 Tonnes per hour.

Supply of roadstone for large contracts is generally by tender with considerable pressure on price. A faulty batch of roadstone must be planed up and relaid, often with additional lane rental charges, at a cost which may be orders of magnitude higher than the original price, so sophisticated control systems are a necessity.

Sand

One key ingredient of most roadstones is sand. Sand generally has a high water content. Boiling off this water is a large part of the energy cost of heating the aggregate, in turn a significant part of the overall cost of operation. The water content of sand also varies considerably, especially when stored outdoors, being typically of the order of some tens of percent of the overall mass of wet sand. Since sand takes the form of small grains, with a high surface area per unit volume, and binder attaches to the surface of the aggregates, the amount of dry sand in the mix is particularly critical to the overall blend; the moisture content must be measured and the equivalent dry weight calculated.

Binder

Binder comes in different grades known as "penetration" or "pen" grades, with values varying between around 30 and 300. The pen value is an expression of the depth to which a standard needle will penetrate the surface of the binder at a specified temperature (the higher the value, the softer the binder). This has an effect on the workability of hot asphalt and the stiffness of the asphalt when cooled. Lower pen values give harder wearing. Asphalt wearing courses are typically 35-50 pen, base courses will be higher, typically 200 or 300 pen. The coating plant may combine binder of different grades to achieve a grade between those held on site.

Filler

Filler, as the name implies, fills the voids between aggregate grains and improves the wearing capabilities of the overall mix. It is stored and fed dry into the mix, during or after addition of binder. A common source of filler is fines from the heating process recovered by bag filters or wet filtration ponds from the exhaust of the heating drum.

Types of plant

Batch heater

A batch heater plant weighs the raw aggregates into a heater drum, where the batch is then heated up to temperature. The hot aggregate is discharged into a mixing drum where (dry) filler and binder are added. The blend is mixed and discharged either directly into the delivery vehicles or into a small weighing and collecting hopper. To increase throughput, the heater can be heating the next batch while the previous is being mixed. Capacity is usually of the order of tens of tonnes per hour.

Batch heater plant is used where short production runs are common (a different recipe can be used on each mix) or where total volume is low. Mobile batch heaters are available.

Continuous

In the continuous plant, raw aggregate is brought up from ground hoppers at a precisely controlled rate and fed into a heater drum similar to that used in the asphalt plant. Once heated it is immediately coated in the same drum (with the binder spraybars situated behind the burner) or in a smaller drum situated immediately behind it. Finished product is almost invariably discharged into a hot store rather than directly into delivery vehicles.

Changing mix is achieved by varying the feed rates of the aggregate, filler and binder feeders, with time delays so that the change of blend occurs at the same point in the coating drum. Sand tends to move more slowly through the heating drum, so the blend proportions will not necessarily change at the same point on the feed conveyor. It is common to divert a small amount of material to a waste chute when the transition point reaches the hot elevator.

Drum mix plants are not really suitable for short production runs; although with sophisticated controls the change of mix can be accurate to within some seconds, production rates of hundreds of tonnes per hour may equate to a tonne every ten seconds or so.

Hot storage

Finished roadstone must be kept heated to avoid setting. It is commonly stored in large electrically heated insulated stainless steel silos, from which it is weighed into delivery vehicles. This may be achieved by intermediate weigh hoppers (which may shuttle between hoppers) or by mounting the hoppers directly on load cells. Control of loadout by this method involves accurately predicting the material "in flight" between the discharge door and the vehicle.

Control

Precise control is a necessity. Asphalt mixing and loadout plant typically use a combination of industrialised computer control and programmable logic controllers to achieve this.

With asphalt being a real-time product, timing is important when it comes to delivering product amounts to job sites, etc. 2008 has provided plants with a level of control over equipment by utilizing GPS, RFID and other forms of tracking systems. Tracking provides information throughout the supply chain to make sure that the right amount and type of product is delievered to the correct site in a timely manner and with better accuracy.

Chapter-6

Direct Digital Manufacturing and Contract Manufacturer

Direct digital manufacturing

Direct digital manufacturing, sometimes called **rapid**, **direct**, **instant**, or **on-demand manufacturing**, is a manufacturing process which creates physical parts directly from 3D CAD files or data using computer-controlled additive and subtractive fabrication and machining techniques with minimal human intervention. When a small, low-cost device is used, it is also called **desktop** or **personal manufacturing**.

Additive manufacturing

Additive manufacturing is also referred to as Additive Freeform Fabrication, Rapid Prototyping, Layered manufacturing or 3D printing. This technique physically constructs or manifests 3D geometries directly from 3D CAD. The history of the process begins in the mid-1980s. It was originally known as Rapid Prototyping because the technology was used to make prototypes of parts without having to invest the time or resources to develop tooling or other traditional methods. As the process and quality controls have evolved, the market for additive manufacturing has grown to include production applications.

Additive Manufacturing or Direct Digital Manufacturing is an extension of Rapid Prototyping to real parts for use as final products (not prototypes). As of 2010, the equipment has become competitive with traditional manufacturing techniques in terms of price, speed, reliability, and cost of use. This has led to the expansion of its use in industry. There has been explosive growth in the sales and distribution of the hardware. A new industry has emerged to create software to enable more effective use of the technology, one use of which is the customization of products for consumers. The number of materials that the industry uses increased greatly in the decade to 2007. Modern machines can utilize a broad array of plastics & metals.

As the speed, reliability, and accuracy of the hardware improves, additive manufacturing may replace or complement traditional manufacturing in creating end-use products. One

advantage often cited is that Additive manufacturing eliminates much of the labor associated with traditional manufacturing. Another often cited example is that production can make any number of complex products simultaneously so long as the parts will fit within the build envelope of the machine.

One of the main technologies used for additive manufacturing is Selective laser sintering, a process which uses laser energy to fuse material to create a solid object. Another technology is called Fused Deposition Modeling (FDM), which is commonly used for rapid prototyping but is becoming more and more popular in direct digital manufacturing.

The use of the technology is likely to grow. In 2007 a sub-$4,000 machine was presented. 3D printing bureaus have sprung up around the globe. The RepRap machine is a do-it-yourself rapid prototyping machine with limited use except for demonstration purposes, however, the machine is cheap to build and is constructed of commonly available materials.

Advantages

1. Energy efficiency: Only the energy necessary to form the part is expended, and waste is eliminated. This contrasts with conventional machining, in which energy is used to smelt metal into ingots, which become billet materials. These billet materials are then machined, removing a great deal of the material to produce the final part. The energy used to create the original block of material is wasted.
2. Low material waste: Since the process only forms the desired part, there is almost no waste formed, again in contrast to conventional machining. The absence of waste enhances energy efficiency, as energy is not used to transport or dispose of waste. With the elimination of traditional parts machining, petroleum-based cooling fluids are no longer a necessary waste byproduct.
3. Speed: Generally the actual 3D print process is far slower than traditional techniques, however, traditional techniques often require ancillary processes and procedures (intermediate steps) to form the final product. 3D printing technologies eliminate these steps. Considering this, products can be brought to market faster and sometimes cheaper by using 3D printing rather than traditional processes such as castings and forgings. Since no special tooling is required, 3D parts can be built in hours or days.
4. Complex Geometries: Additive manufacturing technologies allow designing to the process and the creation of more efficient designs without limitations of other processes. Internal passages and features can be created that could not be created with traditional methods.

Example of metal object produced by 3d printing

Materials

METALS: A variety of metals are currently available including alloys of 17-4 and 15-5 Stainless Steel, Maraging Steel, Cobalt Chromium, Inconel 625 and 718, and Titanium Ti6AlV4. Almost any alloy metal can be used in this process once fully developed and validated. These materials are not considered to be compliant with ASME specifications for the grades of metals they represent and are generally considered "approximately similar to" the material grades they mimic.

POLYMERS The variety of non-metallic materials used includes an array of photopolymers based on acrylics as well as an assortment of wax-like substances and even ABS plastic. It is important to note that many of these materials are not considered production-grade as they are brittle, lack good mechanical properties and generally age poorly. Also, the exact compositions of these materials is a closely guarded secret of the manufacturers.

Applications

Applications using this technology include direct parts for a variety of industries including aerospace, automotive, dental, fashion, military, medical and other industries that use complex parts of small to medium size. The Tooling industry uses it to make direct tooling inserts. In particular production of small batches or one off components. Often products can be optimized by taking complex geometries with multiple components in an assembly and simplifying it to fewer sub components and joints. This

is one of the key advantages of the technology. Build volumes of existing equipment continue to grow and as the hardware becomes faster along with larger volumes, new uses become feasible.

Technologies

There are presently about 25 3D printing technologies (This list is not all inclusive). The oldest is layered object manufacturing. The next oldest is stereolithography. More recent technologies include selective laser sintering, Direct Metal Laser Sintering (DMLS), inkjet technologies, fused deposition modeling, Polyjet matrix and many variations. All of these technologies take a 3D model, compute cross-sections of that model, and then deposit the cross-sections sequentially on top of each other until the final geometry is achieved. Overhanging parts are supported by a second material in many cases or by the material in powdered form such as in the case of Selective Laser Sintering.

To visualize how 3D printing works, consider a coffee cup. If you were to slice the coffee cup into wafer-thin layer like you would meat on a slicing machine at a Deli and save each layer and then re-stack them in order, you would re-create the shape of the original object. 3D printing accomplishes this by deposition of very thin layers on top of each other from sliced 3D models or CAD data within a computer system.

Varying the layer thickness affects the model surface finish and other parameters including but not limited to mechanical properties. Many methods have been devised to improve surface finishes; these usually slow down the printing process.

Direct Digital Manufacturing Usage

In 2006 there were approximately 50 commercially viewable examples of 3D printing being used for tooling or intermediate parts. The technology is still new and its use is directly dependent on users' knowledge of engineering to design a part and effectively use the printing equipment. The growth of the market is nevertheless fast, and was estimated in 2006 to be as high as 35% annually.

The earliest use of the term Direct Digital Manufacturing surfaced around 2004 by Digital Reality, Inc. The company purportedly holds a patent pending on a process for Direct Digital Manufacturing they call Made-To-Order Digital Manufacturing Enterprise. The company filed a non-publication request on the patent application.

Contract manufacturer

A **contract manufacturer** ("CM") is a manufacturer that contracts with a firm for components or products. It is a form of outsourcing.

Business model

In a contract manufacturing business model, the hiring firm approaches the contract manufacturer with a design or formula. The contract manufacturer will quote the parts based on processes, labor, tooling, and material costs. Typically a hiring firm will request quotes from multiple CMs. After the bidding process is complete, the hiring firm will select a source, and then, for the agreed-upon price, the CM acts as the hiring firm's factory, producing and shipping units of the design on behalf of the hiring firm.

Industries that utilize the practice

Many industries utilize this process, especially the aerospace, defense, computer, semiconductor, energy, medical, food manufacturing, personal care, and automotive fields. Some types of contract manufacturing include CNC machining, complex assembly, aluminum die casting, grinding, broaching, gears, and forging. The pharmaceutical industry utilizes this process with CMs called Contract manufacturing organizations.

Why Contract Manufacture?

There are many benefits as well as risks to contract manufacturing. Companies are finding many reasons why they should be outsourcing their production to other companies. However, production outside of the company does come with many risks attached. Companies must identify what their core competencies are first before deciding whether or not they should contract manufacture. A company's core competencies are what make them competitive in the market place. If a company allows another company to take control of them, it loses control over that advantage. When making the decision on whether or not a company should contract manufacture, the company should weigh the benefits and risks associated with it. For small companies, contract manufacturing may not be a good business strategy. For large companies that are trying to grow and extend into new markets, contract manufacturing is likely to be a good choice.

Benefits

- Cost Savings – Companies save on their cost of capital because they do not have to pay for a facility and the equipment needed for production. Some companies may look to contract manufacture in low-cost countries, such as China, to benefit from the low cost of labor.
- Focus – Companies place purchase orders for their products and can then focus more on marketing and sales.
- Mutual Benefit to Contract Site – A contract between the manufacturer and the company it's producing for may last several years. The manufacturer will know that it will have a steady flow of business until then.
- Advanced Skills – Companies can take advantage of skills that they may not possess, but the contract manufacturer does. The contract manufacturer is likely to

have relationships formed with raw material suppliers or methods of efficiency within their production.

- Quality – Contract Manufacturers are likely to have their own methods of qualitycontrol in place that helps them to detect counterfeit or damaged materials early on.
- Core Competencies– Companies can focus on their core competencies better if they can hand off base production to an outside company.
- Economies of Scale – Contract Manufacturers have multiple customers that they produce for. Because they are servicing multiple customers, they can offer reduced costs in acquiring raw materials by benefiting from economies of scale. The more units there are in one shipment, the less expensive the price per unit will be.

Risks

- Lack of Control – As soon as a company signs the contract allowing another company to produce their product, they loose a significant amount of control over that product. They can only suggest strategies to the contract manufacturer; they cannot force them to implement them.
- Relationships - It is imperative that the company forms a good relationship with its contract manufacture. The company must keep in mind that it is not the only customer to the manufacturer. They cannot force them to produce their product before a competitor's. Most companies mitigate this risk by working cohesively with the manufacturer and awarding good performance with more of their business.
- Quality concerns – When entering into a contract, companies must make sure that the manufacturer's standards are in line with their own. They should also evaluate the methods in which they test product to make sure the products being produced are of good quality. The company has to rely on the contract manufacturer for having good suppliers that also meet these standards.
- Intellectual Property Loss – When entering into a contract, a company is letting someone else in on their formulas or technologies. This is why it is very important that a company not give out any of its core competencies to contract manufacturers. It is very easy for an employee to download such information from a computer and steal it. The recent uptake in intellectual property loss has companies and government officials struggling to find the best method of security. Usually, it comes down to the integrity of the employees.
- Outsourcing Risks – Although outsourcing to low-cost countries has become very popular, it does bring along risks such as language barriers, cultural differences and long lead times.
- Capacity Constraints – If a company does not make up a large portion of the contract manufacturer's business, they may find that they are de-prioritized over other companies during high production periods. Thus, they may not be able to get the product they need when they need it.

Protectionism

In an international context, establishing a foreign subsidiary as a contract manufacturer can have favorable tax benefits for the parent company, allowing them to reduce overall tax liabilities and increase profits, depending upon the activities of the contract manufacturer. This is a form of protectionism.

Chapter-7

Digital Prototyping

Digital Prototyping gives conceptual design, engineering, manufacturing, and sales and marketing departments the ability to virtually explore a complete product before it's built. Industrial designers, manufacturers, and engineers use Digital Prototyping to design, iterate, optimize, validate, and visualize their products digitally throughout the product development process. Marketers also use Digital Prototyping to create photorealistic renderings and animations of products prior to manufacturing. Companies often adopt Digital Prototyping with the goal of improving communication between product development stakeholders, getting products to market faster, and facilitating product innovation.

Digital Prototyping goes beyond simply creating product designs in 3D. It gives product development teams a way to assess the operation of moving parts, to determine whether or not the product will fail, and see how the various product components interact with subsystems—either pneumatic or electric. By simulating and validating the real-world performance of a product design digitally, manufacturers often can reduce the number of physical prototypes they need to create before a product can be manufactured, reducing the cost and time needed for physical prototyping. Many companies use Digital Prototyping in place of, or as a complement to, physical prototyping.

Digital Prototyping changes the traditional product development cycle from design>build>test>fix to design>analyze>test>build. Instead of needing to build multiple physical prototypes and then testing them to see if they'll work, companies can conduct testing digitally throughout the process by using Digital Prototyping, reducing the number of physical prototypes needed to validate the design. Studies show that by using Digital Prototyping to catch design problems up front, manufacturers experience fewer change orders downstream. Because the geometry in digital prototypes is highly accurate, companies can check interferences to avoid assembly issues that generate change orders in the testing and manufacturing phases of development. Companies can also perform simulations in early stages of the product development cycle, so they avoid failure modes during testing or manufacturing phases. With a Digital Prototyping approach, companies can digitally test a broader range of their product's performance. They can also test design iterations quickly to assess whether they're over- or under-designing components.

Research from the Aberdeen Group shows that manufacturers that use Digital Prototyping build half the number of physical prototypes as the average manufacturer, get to market 58 days faster than average, and experience 48 percent lower prototyping costs.

History of Digital Prototyping

The concept of Digital Prototyping has been around for over a decade, particularly since software companies such as Autodesk, PTC, Siemens PLM (formerly UGS), and Dassault began offering computer-aided design (CAD) software capable of creating accurate 3D models.

It may even be argued that the product lifecycle management (PLM) approach was the harbinger of Digital Prototyping. PLM is an integrated, information-driven approach to a product's lifecycle, from development to disposal. A major aspect of PLM is coordinating and managing product data among all software, suppliers, and team members involved in the product's lifecycle. Companies use a collection of software tools and methods to integrate people, data, and processes to support singular steps in the product's lifecycle or to manage the product's lifecycle from beginning to end. PLM often includes product visualization to facilitate collaboration and understanding among the internal and external teams that participate in some aspect of a product's lifecycle.

While the concept of Digital Prototyping has been a longstanding goal for manufacturing companies for some time, it's only recently that Digital Prototyping has become a reality for small-to-midsize manufacturers that cannot afford to implement complex and expensive PLM solutions.

Digital Prototyping and PLM

Large manufacturing companies rely on PLM to link otherwise unconnected, siloed activities, such as concept development, design, engineering, manufacturing, sales, and marketing. PLM is a fully integrated approach to product development that requires investments in application software, implementation, and integration with enterprise resource planning (ERP) systems, as well as end-user training and a sophisticated IT staff to manage the technology. PLM solutions are highly customized and complex to implement, often requiring a complete replacement of existing technology. Because of the high expense and IT expertise required to purchase, deploy, and run a PLM solution, many small-to-midsized manufacturers cannot implement PLM.

Digital Prototyping is a viable alternative to PLM for these small-to-midsized manufacturers. Like PLM, Digital Prototyping seeks to link otherwise unconnected, siloed activities, such as concept development, design, engineering, manufacturing, sales, and marketing. However, unlike PLM, Digital Prototyping does not support the entire product development process from conception to disposal, but rather focuses on the design-to-manufacture portion of the process. The realm of Digital Prototyping ends when the digital product and the engineering bill of materials are complete. Digital Prototyping aims to resolve many of the same issues as PLM without involving a highly

customized, all-encompassing software deployment. With Digital Prototyping, a company may choose to address one need at a time, making the approach more pervasive as its business grows. Other differences between Digital Prototyping and PLM include:

- Digital Prototyping involves fewer participants than PLM.
- Digital Prototyping has a less complex process for collecting, managing, and sharing data.
- Manufacturers can keep product development activities separate from operations management with Digital Prototyping.
- Digital Prototyping solutions don't need to be integrated with ERP (but can be), customer relationship management (CRM), and project and portfolio management (PPM) software.

Digital Prototyping Workflow

A Digital Prototyping workflow involves using a single digital model throughout the design process to bridge the gaps that typically exist between workgroups such as industrial design, engineering, manufacturing, sales, and marketing. Product development can be broken into the following general phases at most manufacturing companies:

- Conceptual Design
- Engineering
- Manufacturing
- Customer Involvement
- Marketing Communications

Conceptual Design

The conceptual design phase involves taking customer input or market requirements and data to create a product design. In a Digital Prototyping workflow, designers work digitally, from the very first sketch, throughout the conceptual design phase. They capture their designs digitally, and then share that data with the engineering team using a common file format. The industrial design data is then incorporated into the digital prototype to ensure technical feasibility.

In a Digital Prototyping workflow, designers and their teams review digital design data via high-quality digital imagery or renderings to make informed product design decisions. Designers may create and visualize several iterations of design, changing things like materials or color schemes, before a concept is finalized.

Engineering

During the engineering phase of the Digital Prototyping workflow, engineers create the product's 3D model (the digital prototype), integrating design data developed during the conceptual design phase. Teams also add electrical systems design data to the digital prototype while it's being developed, and evaluate how different systems interact. At this

stage of the workflow, all data related to the product's development is fully integrated into the digital prototype. Working with mechanical, electrical, and industrial design data, companies engineer every last product detail in the engineering phase of the workflow. At this point, the digital prototype is a fully realistic digital model of the complete product.

Engineers test and validate the digital prototype throughout their design process to make the best possible design decisions and avoid costly mistakes. Using the digital prototype, engineers can:

- Perform integrated calculations, and stress, deflection, and motion simulations to validate designs
- Test how moving parts will work and interact
- Evaluate different solutions to motion problems
- Test how the design functions under real-world constraints
- Conduct stress analysis to analyze material selection and displacement
- Verify the strength of a part

By incorporating integrated calculations, stress, deflection, and motion simulations into the Digital Prototyping workflow, companies can speed development cycles by minimizing physical prototyping phases.

Also during the engineering phase of the Digital Prototyping workflow, engineers create documentation required by the production team.

Manufacturing

In a Digital Prototyping workflow, manufacturing teams are involved early in the design process. This input helps engineers and manufacturing experts work together on the digital prototype throughout the design process to ensure that the product can be produced cost effectively. Manufacturing teams can see the product exactly as it's intended, and provide input on manufacturability. Companies can perform molding simulations on digital prototypes for plastic part and injection molds to test the manufacturability of their designs, identifying potential manufacturing defects before they cut mold tooling.

Digital Prototyping also enables product teams to share detailed assembly instructions digitally with manufacturing teams. While paper assembly drawings can be confusing, 3D visualizations of digital prototypes are unambiguous. This early and clear collaboration between manufacturing and engineering teams helps minimize manufacturing problems on the shop floor.

Finally, manufacturers can use Digital Prototyping to visualize and simulate factory-floor layouts and production lines. They can check for interferences to detect potential issues such as space constraints and equipment collisions.

Customer Involvement

Customers are involved throughout the Digital Prototyping workflow. Rather than waiting for a physical prototype to be complete, companies that use Digital Prototyping bring customers into the product development process early. They show customers realistic renderings and animations of the product's digital prototype so they'll know what the product looks like and how it will function. This early customer involvement helps companies get sign-off up front, so they don't waste time designing, engineering, and manufacturing a product that doesn't fulfill the customer's expectations.

Marketing

Using 3D CAD data from the digital prototype, companies can create realistic visualizations, renderings, and animations to market products in print, on the web, in catalogues, or in television commercials. Without needing to produce expensive physical prototypes and conduct photo shoots, companies can create virtual photography and cinematography nearly indistinguishable from reality.one aspect of this is creating the illumination environment for the subject, an area of new development.

Realistic visualizations not only help marketing communications, but the sales process as well. Companies can respond to requests for proposals and bid on projects without building physical prototypes, using visualizations to show the potential customer what the end product will be like. In addition, visualizations can help companies bid more accurately by making it more likely that everyone has the same expectations about the end product. Companies can also use visualizations to facilitate the review process once they've secured the business. Reviewers can interact with digital prototypes in realistic environments, allowing for the validation of design decisions early in the product development process.

Connecting Data and Teams

To support a Digital Prototyping workflow, companies use data management tools to coordinate all teams at every stage in the workflow, streamline design revisions and automate release processes for digital prototypes, and manage engineering bills of materials. These data management tools connect all workgroups to critical Digital Prototyping data.

Digital Prototyping and Sustainability

Companies increasingly use Digital Prototyping to understand sustainability factors in new product designs, and to help meet customer requirements for sustainable products and processes. They minimize material use by assessing multiple design scenarios to determine the optimal amount and type of material required to meet product specifications. In addition, by reducing the number of physical prototypes required, manufacturers can trim down their material waste.

Digital Prototyping can also help companies reduce the carbon footprint of their products. For example, WinWinD, a company that creates innovative wind turbines, uses Digital Prototyping to optimize the energy production of wind-power turbines for varying wind conditions. Furthermore, the rich product data supplied by Digital Prototyping can help companies demonstrate conformance with the growing number of product-related environmental regulations and voluntary sustainability standards.

Chapter-8

Factory

Volkswagen factory in Wolfsburg, Germany.

A **factory** (previously **manufactory**) or **manufacturing plant** is an industrial building where laborers manufacture goods or supervise machines processing one product into another. Most modern factories have large warehouses or warehouse-like facilities that contain heavy equipment used for assembly line production. Typically, factories gather and concentrate resources: laborers, capital and plant.

History

Entrance to the Venetian Arsenal by Canaletto, 1732.

The assembly plant of the Bell Aircraft Corporation at Wheatfield, New York, United States, 1944

A factory worker in 1940s Fort Worth, Texas, United States.

Although large mills and workshops were established in ancient China, Rome and the Middle East, the Venice Arsenal provides one of the first examples of a factory in the modern sense of the word. Founded in 1104 in Venice, Republic of Venice, several hundred years before the Industrial Revolution, it mass-produced ships on assembly lines using manufactured parts. The Venice Arsenal apparently produced nearly one ship every day and, at its height, employed 16,000 people.

Many historians regard Matthew Boulton's Soho Manufactory (established in 1761 in Birmingham) as the first modern factory. (Other claims might be made for John Lombe's silk mill in Derby (1721), or Richard Arkwright's Cromford Mill (1771)—purpose built to fit the equipment it held and taking the material through the various manufacturing processes.) One historian, Jack Weatherford, contends that the first factory was in Potosí, for processing silver ingot slugs into coins, because there was so much silver being mined close by.

British colonies in the late 18th century built factories simply as buildings where a large number of laborers gathered to perform hand labor, usually in textile production. This proved more efficient—for administration and for the distribution of raw materials to

individual laborers—than earlier methods of manufacturing such as cottage industries or the putting-out system.

Cotton mills used inventions such as the steam engine and the power loom to pioneer the industrial factory of the 19th century, where precision machine tools and replaceable parts allowed greater efficiency and less waste.

Between 1820 and 1850, the non-mechanized factories supplanted the traditional artisan shops as the predominant form of manufacturing institution. Even though the theory on why and how the non-mechanized factories gradually replaced the small artisan shops is still ambiguous, what is apparent is that the larger-scale factories enjoyed technological gains and advance in efficiency over the small artisan shops. In fact, the larger scale forms of factory establishments were more favorable and advantageous over the small artisan shops in terms of competition for survival.

Henry Ford further revolutionized the factory concept in the early 20th century, with the innovation of mass production. Highly specialized laborers situated alongside a series of rolling ramps would build up a product such as (in Ford's case) an automobile. This concept dramatically decreased production costs for virtually all manufactured goods and brought about the age of consumerism.

In the mid- to late 20th century, industrialized countries introduced next-generation factories with two improvements:

1. Advanced statistical methods of quality control, pioneered by the American mathematician William Edwards Deming, whom his home country initially ignored. Quality control turned Japanese factories into world leaders in cost-effectiveness and production quality.
2. Industrial robots on the factory floor, introduced in the late 1970s. These computer-controlled welding arms and grippers could perform simple tasks such as attaching a car door quickly and flawlessly 24 hours a day. This too cut costs and improved speed.

Some speculation as to the future of the factory includes scenarios with rapid prototyping, nanotechnology, and orbital zero-gravity facilities.

Siting the factory

Before the advent of mass transportation, factories' needs for ever-greater concentrations of laborers meant that they typically grew up in an urban setting or fostered their own urbanization. Industrial slums developed, and reinforced their own development through the interactions between factories, as when one factory's output or waste-product became the raw materials of another factory (preferably nearby). Canals and railways grew as factories spread, each clustering around sources of cheap energy, available materials and/or mass markets. The exception proved the rule: even greenfield factory sites such as

Bournville, founded in a rural setting, developed its own housing and profited from convenient communications systems.

Regulation curbed some of the worst excesses of industrialization's factory-based society, a series of Factory Acts leading the way in Britain. Trams, automobiles and town planning encouraged the separate development of industrial suburbs and residential suburbs, with laborers commuting between them.

Though factories dominated the Industrial Era, the growth in the service sector eventually began to dethrone them: the focus of labor in general shifted to central-city office towers or to semi-rural campus-style establishments, and many factories stood deserted in local rust belts.

The next blow to the traditional factories came from globalization. Manufacturing processes (or their logical successors, assembly plants) in the late 20th century re-focussed in many instances on Special Economic Zones in developing countries or on maquiladoras just across the national boundaries of industrialized states. Further re-location to the least industrialized nations appears possible as the benefits of out-sourcing and the lessons of flexible location apply in the future.

New England factories in the 19th century

In New England in the early to mid-19th century, many cotton and textile factories employed large numbers of female adolescent laborers from the New England area. The girls came from families of middling farmers. Factory employment offered an alternative to rural lifestyle, and many women labored, not only to send money back home, but to gain greater social & economic independence. They were able to earn enough at the factory to cover their living expenses and still have spending money and savings for dowries.

In 1834 New England textile factory owners decided to cut the wages of these young women in order to save money. In response, the young factory laborers organized turnouts (strikes) in an attempt to force their employers to raise wages again. These young women viewed themselves as equals to their managers. They saw their wage reductions as attempts to take away their economic independence and force them to become completely dependent upon factory employment for survival—to make them "slaves" to their employers. Because of bad timing and poor organization their 1834 factory turnout was unsuccessful, but it did lay the foundation for successful strikes that helped shape factory life in the future.

Governing the factory

Much of management theory developed in response to the need to control factory processes. Assumptions on the hierarchies of unskilled, semi-skilled and skilled laborers and their supervisors and managers still linger on; however an example of a more

contemporary approach to handle design applicable to manufacturing facilities can be found in Socio-Technical Systems (STS).

Shadow factories

A **shadow factory** is a term given to dispersed manufacturing sites in times of war to reduce the risk of disruption due to enemy air-raids and often with the dual purpose of increasing manufacturing capacity.

Production of the Supermarine Spitfire at its parent company's base at Woolston, Southampton was vulnerable to enemy attack as a high profile target and was well within range of *Luftwaffe* bombers. Indeed on 26 September 1940 this facility was completely destroyed by an enemy bombing raid. Supermarine had already established a plant at Castle Bromwich, this action prompted them to further disperse Spitfire production around the country with many premises being requisitioned by the British Government.

Connected to the Spitfire was production of its equally important Rolls-Royce Merlin engine, Rolls-Royce's main aero engine facility was located at Derby, the need for increased output was met by building new factories in Crewe and Glasgow and using a purpose-built factory of Ford of Britain in Trafford Park Manchester.

Chapter-9

Packaging and Labeling

Tablets in a blister pack, which was itself packaged in a folding carton made of paperboard.

Packaging is the science, art, and technology of enclosing or protecting products for distribution, storage, sale, and use. Packaging also refers to the *process* of design, evaluation, and production of packages. Packaging can be described as a *coordinated system* of preparing goods for transport, warehousing, logistics, sale, and end use. Packaging contains, protects, preserves, transports, informs, and sells. In many countries it is fully integrated into government, business, institutional, industrial, and personal use.

Package labelling (en-GB) or **labeling** (en-US) is any written, electronic, or graphic communications on the packaging or on a separate but associated label.

History

The first packages used the natural materials available at the time: Baskets of reeds, wineskins (Bota bags), wooden boxes, pottery vases, ceramic amphorae, wooden barrels, woven bags, etc. Processed materials were used to form packages as they were developed: for example, early glass and bronze vessels. The study of old packages is an important aspect of archaeology.

The earliest recorded use of paper for packaging dates back to 1035, when a Persian traveler visiting markets in Cairo noted that vegetables, spices and hardware were wrapped in paper for the customers after they were sold.

Iron and tin plated steel were used to make cans in the early 19th century. Paperboard cartons and corrugated fiberboard boxes were first introduced in the late 19th century.

Packaging advancements in the early 20th century included Bakelite closures on bottles, transparent cellophane overwraps and panels on cartons, increased processing efficiency and improved food safety. As additional materials such as aluminum and several types of plastic were developed, they were incorporated into packages to improve performance and functionality.

In-plant recycling has long been common for production of packaging materials. Post-consumer recycling of aluminum and paper based products has been economical for many years: since the 1980s, post-consumer recycling has increased due to curbside recycling, consumer awareness, and regulatory pressure.

As of 2003, the packaging sector accounted for about two percent of the gross national product in developed countries. About half of this market was related to food packaging.

Early wooden wine barrel

Heroin bottle and carton, 1914

The purposes of packaging and package labels

Diced pork in tray and film overwrap. Label indicates net weight, composition, preparation, etc. The Union Flag, British Farm Standard tractor logo, and British Meat Quality Standard logo are also present.

Packaging and package labeling have several objectives

- **Physical protection** - The objects enclosed in the package may require protection from, among other things, mechanical shock, vibration, electrostatic discharge, compression, temperature, etc.
- **Barrier protection** - A barrier from oxygen, water vapor, dust, etc., is often required. Permeation is a critical factor in design. Some packages contain desiccants or Oxygen absorbers to help extend shelf life. Modified atmospheres or controlled atmospheres are also maintained in some food packages. Keeping the contents clean, fresh, sterile and safe for the intended shelf life is a primary function.
- **Containment or agglomeration** - Small objects are typically grouped together in one package for reasons of efficiency. For example, a single box of 1000 pencils requires less physical handling than 1000 single pencils. Liquids, powders, and granular materials need containment.

- **Information transmission** - Packages and labels communicate how to use, transport, recycle, or dispose of the package or product. With pharmaceuticals, food, medical, and chemical products, some types of information are required by governments. Some packages and labels also are used for track and trace purposes.
- **Marketing** - The packaging and labels can be used by marketers to encourage potential buyers to purchase the product. Package graphic design and physical design have been important and constantly evolving phenomenon for several decades. Marketing communications and graphic design are applied to the surface of the package and (in many cases) the point of sale display.
- **Security** - Packaging can play an important role in reducing the security risks of shipment. Packages can be made with improved tamper resistance to deter tampering and also can have tamper-evident features to help indicate tampering. Packages can be engineered to help reduce the risks of package pilferage: Some package constructions are more resistant to pilferage and some have pilfer indicating seals. Packages may include authentication seals and use security printing to help indicate that the package and contents are not counterfeit. Packages also can include anti-theft devices, such as dye-packs, RFID tags, or electronic article surveillance tags that can be activated or detected by devices at exit points and require specialized tools to deactivate. Using packaging in this way is a means of loss prevention.
- **Convenience** - Packages can have features that add convenience in distribution, handling, stacking, display, sale, opening, reclosing, use, dispensing, and reuse.
- **Portion control** - Single serving or single dosage packaging has a precise amount of contents to control usage. Bulk commodities (such as salt) can be divided into packages that are a more suitable size for individual households. It is also aids the control of inventory: selling sealed one-liter-bottles of milk, rather than having people bring their own bottles to fill themselves.

Packaging types

Various household packaging types for foods

Packaging may be looked at as being of several different types. For example a **transport package** or **distribution package** can be the shipping container used to ship, store, and handle the product or inner packages. Some identify a **consumer package** as one which is directed toward a consumer or household.

Packaging may be described in relation to the type of product being packaged: medical device packaging, bulk chemical packaging, over-the-counter drug packaging, retail food packaging, military materiel packaging, pharmaceutical packaging, etc.

Aluminum can with an easy open lid

It is sometimes convenient to categorize packages by layer or function: "primary", "secondary", etc.

- Primary packaging is the material that first envelops the product and holds it. This usually is the smallest unit of distribution or use and is the package which is in direct contact with the contents.
- Secondary packaging is outside the primary packaging, perhaps used to group primary packages together.
- Tertiary packaging is used for bulk handling, warehouse storage and transport shipping. The most common form is a palletized unit load that packs tightly into containers.

These broad categories can be somewhat arbitrary. For example, depending on the use, a shrink wrap can be primary packaging when applied directly to the product, secondary packaging when combining smaller packages, and tertiary packaging on some distribution packs.

Symbols used on packages and labels

Many types of symbols for package labeling are nationally and internationally standardized. For consumer packaging, symbols exist for product certifications, trademarks, proof of purchase, etc. Some requirements and symbols exist to communicate aspects of consumer use and safety, for example the estimated sign that notes conformance to EU weights and measures accuracy regulations. Examples of environmental and recycling symbols include the recycling symbol, the resin identification code and the "Green Dot".

Bar codes , Universal Product Codes, and RFID labels are common to allow automated information management in logistics and retailing. Country of Origin Labeling is often used.

Shipping container labeling

"Print & Apply" corner wrap UCC (GS1-128) label application to a pallet load

Technologies related to shipping containers are identification codes, bar codes, and electronic data interchange (EDI). These three core technologies serve to enable the business functions in the process of shipping containers throughout the distribution channel. Each has an essential function: identification codes either relate product information or serve as keys to other data, bar codes allow for the automated input of identification codes and other data, and EDI moves data between trading partners within the distribution channel.

Elements of these core technologies include UPC and EAN item identification codes, the SCC-14 (UPC shipping container code), the SSCC-18 (Serial Shipping Container Codes), Interleaved 2-of-5 and UCC/EAN-128 (newly designated GS1-128) bar code symbologies, and ANSI ASC X12 and UN/EDIFACT EDI standards.

Small parcel carriers often have their own formats. For example, United Parcel Service has a MaxiCode 2-D code for parcel tracking.

RFID labels for shipping containers are also increasing in usage. A Wal-Mart division, Sam's Club, has also moved in this direction and is putting pressure on its suppliers for compliance.

Shipments of hazardous materials or dangerous goods have special information and symbols (labels, plackards, etc.) as required by UN, country, and specific carrier requirements. Two examples are below:

With transport packages, standardised symbols are also used to communicate handling needs. Some common ones are shown below while others are listed in ASTM D5445 "Standard Practice for Pictorial Markings for Handling of Goods" and ISO 780 "Pictorial marking for handling of goods".

Fragile

Do not use hand hooks

This way up

Keep away from sunlight

Keep away from water

Centre of gravity

Clamp as indicated

Do not clamp as indicated

Package development considerations

Package design and development are often thought of as an integral part of the new product development process. Alternatively, development of a package (or component) can be a separate process, but must be linked closely with the product to be packaged. Package design starts with the identification of all the requirements: structural design, marketing, shelf life, quality assurance, logistics, legal, regulatory, graphic design, end-use, environmental, etc. The design criteria, performance (specified by package testing), completion time targets, resources, and cost constraints need to be established and agreed upon.

Palletized and unitized load

Express air shipment of mixed parcels

Transport packaging needs to be matched to its logistics system. Packages designed for controlled shipments of uniform pallet loads may not be suited to mixed shipments with express carriers.

An example of how package design is affected by other factors is the relationship to logistics. When the distribution system includes individual shipments by a small parcel carrier, the sortation, handling, and mixed stacking make severe demands on the strength and protective ability of the transport package. If the logistics system consists of uniform palletized unit loads, the structural design of the package can be designed to those specific needs: vertical stacking, perhaps for a longer time frame. A package designed for one mode of shipment may not be suited for another.

With some types of products, the design process involves detailed regulatory requirements for the package. For example with packaging foods, any package components that may contact the food are food contact materials. Toxicologists and food scientists need to verify that the packaging materials are allowed by applicable regulations. Packaging engineers need to verify that the completed package will keep the product safe for its intended shelf life with normal usage. Packaging processes, labeling, distribution, and sale need to be validated to comply with regulations and have the well being of the consumer in mind.

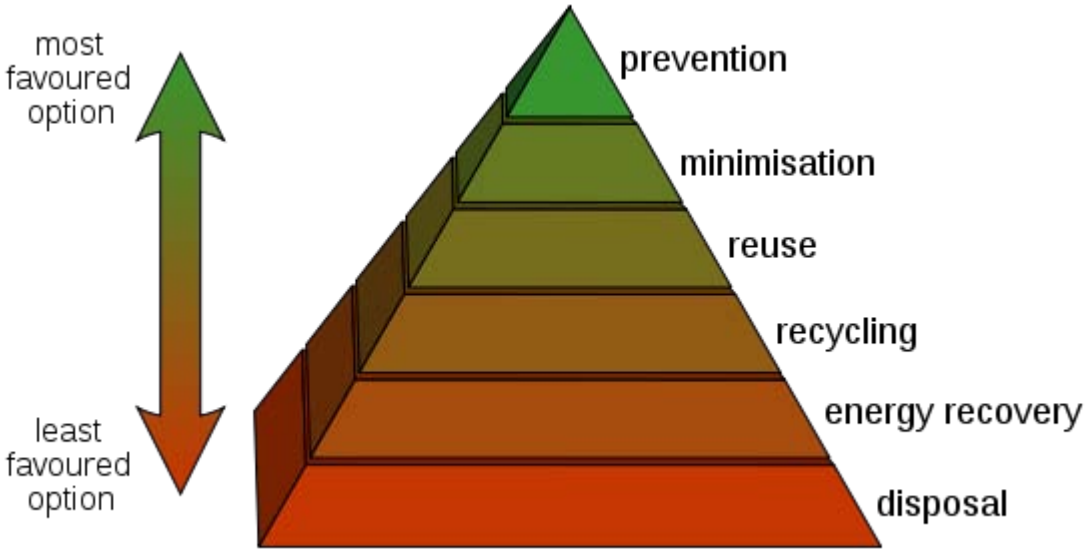
Sometimes the objectives of package development seem contradictory. For example, regulations for an over-the-counter drug might require the package to be tamper-evident and child resistant: These intentionally make the package difficult to open. The intended consumer, however, might be handicapped or elderly and be unable to readily open the package. Meeting all goals is a challenge.

Package design may take place within a company or with various degrees of external packaging engineering: independent contractors, consultants, vendor evaluations, independent laboratories, contract packagers, total outsourcing, etc. Some sort of formal Project planning and Project management methodology is required for all but the simplest package design and development programs. An effective quality management system and Verification and Validation protocols are mandatory for some types of packaging and recommended for all.

Environmental considerations

Package development involves considerations for sustainability, environmental responsibility, and applicable environmental and recycling regulations. It may involve a life cycle assessment which considers the material and energy inputs and outputs to the package, the packaged product (contents), the packaging process, the logistics system, waste management, etc. It is necessary to know the relevant regulatory requirements for point of manufacture, sale, and use.

The traditional “three R’s” of reduce, reuse, and recycle are part of a waste hierarchy which may be considered in product and package development.



The waste hierarchy

- Prevention – Waste prevention is a primary goal. Packaging should be used only where needed. Proper packaging can also help prevent waste. Packaging plays an important part in preventing loss or damage to the packaged-product (contents). Usually, the energy content and material usage of the product being packaged are much greater than that of the package. A vital function of the package is to protect the product for its intended use: if the product is damaged or degraded, its entire energy and material content may be lost.
- Minimization – (also "source reduction") The mass and volume of packaging (per unit of contents) can be measured and used as one of the criteria to minimize during the package design process. Usually “reduced” packaging also helps minimize costs. Packaging engineers continue to work toward reduced packaging.
- Reuse – The reuse of a package or component for other purposes is encouraged. Returnable packaging has long been useful (and economically viable) for closed loop logistics systems. Inspection, cleaning, repair and recouperage are often needed. Some manufacturers re-use the packaging of the incoming parts for a product, either as packaging for the outgoing product or as part of the product itself.
- Recycling – Recycling is the reprocessing of materials (pre- and post-consumer) into new products. Emphasis is focused on recycling the largest primary components of a package: steel, aluminum, papers, plastics, etc. Small components can be chosen which are not difficult to separate and do not contaminate recycling operations.
- Energy recovery – Waste-to-energy and Refuse-derived fuel in approved facilities are able to make use of the heat available from the packaging components.
- Disposal – Incineration, and placement in a sanitary landfill are needed for some materials. Certain states within the US regulate packages for toxic contents, which

have the potential to contaminate emissions and ash from incineration and leachate from landfill. Packages should not be littered.

Development of sustainable packaging is an area of considerable interest by standards organizations, government, consumers, packagers, and retailers.

Packaging machines

Beer bottling lines

A choice of packaging machinery includes: technical capabilities, labor requirements, worker safety, maintainability, serviceability, reliability, ability to integrate into the packaging line, capital cost, floorspace, flexibility (change-over, materials, etc.), energy usage, quality of outgoing packages, qualifications (for food, pharmaceuticals, etc.), throughput, efficiency, productivity, ergonomics, return on investment, etc.

Packaging machinery can be:

1. purchased as standard, off-the-shelf
2. purchased custom-made or custom-tailored to specific operations
3. manufactured or modified by in-house engineers and maintenance staff

Packaging machines may be of the following general types:

- Accumulating and Collating Machines
- Blister packs, skin packs and Vacuum Packaging Machines
- Bottle caps equipment, Over-Capping, Lidding, Closing, Seaming and Sealing Machines
- Box, Case and Tray Forming, Packing, Unpacking, Closing and Sealing Machines
- Cartoning machines
- Cleaning, Sterilizing, Cooling and Drying Machines
- Coding, Printing, Marking, Stamping, and Imprinting Machines
- Converting Machines
- Conveyor belts, Accumulating and Related Machines
- Feeding, Orienting, Placing and Related Machines
- Filling Machines: Handling dry, powered, solid, liquid, gas, or viscous products
- Inspecting, Detecting and Check weigher Machines
- Label dispenser
- Orienting, Unscrambling Machines
- Package Filling and Closing Machines
- Palletizing, Depalletizing, Unit load assembly
- Product Identification: labeling, marking, etc.
- Wrapping machines: Shrink wrap, Banding
- Form, Fill and Seal Machines
- Other speciality machinery: slitters, perforating, laser cutters, parts attachment, etc.
- Process Machinery (Product Preparation): Chopper, Crusher, Cutter, Molder, Peeler, etc.
- Process Machinery (Special Product): Coating, Enrobing, Seasoning
- Process Machinery (Product Cooking, Heating, and Cooling): Aseptic

Bakery goods shrinkwrapped by shrink film, heat sealer and heat tunnel on roller conveyer

Label printer applicator applying a label to adjacent panels of a corrugated box.

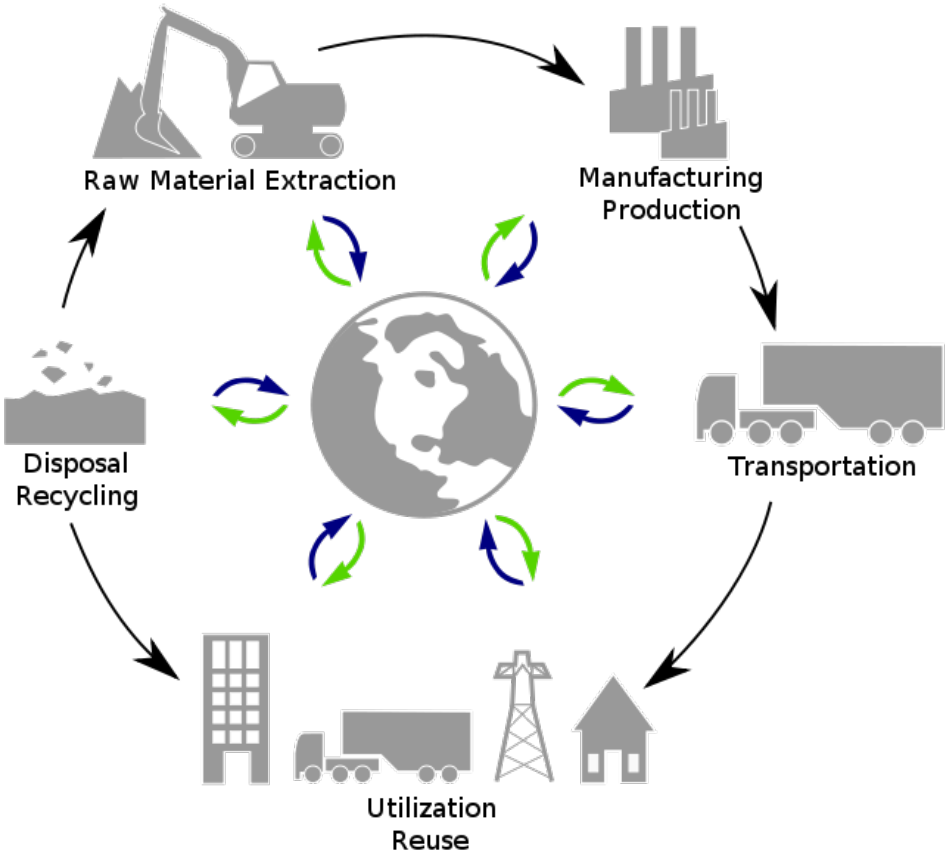
Robotics used to palletize bread

Automated labeling line for wine bottles

Chapter-10

Manufacturing and Manufacturing Resource Planning

Manufacturing



Assembly of Section 41 of a Boeing 787 Dreamliner.

Manufacturing is the use of machines, tools and labor to produce goods for use or sale. The term may refer to a range of human activity, from handicraft to high tech, but is most commonly applied to industrial production, in which raw materials are transformed into finished goods on a large scale. Such finished goods may be used for manufacturing other, more complex products, such as aircraft, household appliances or automobiles, or sold to wholesalers, who in turn sell them to retailers, who then sell them to end users – the "consumers".

Manufacturing takes turns under all types of economic systems. In a free market economy, manufacturing is usually directed toward the mass production of products for sale to consumers at a profit. In a collectivist economy, manufacturing is more frequently directed by the state to supply a centrally planned economy. In free market economies, manufacturing occurs under some degree of government regulation.

Modern manufacturing includes all intermediate processes required for the production and integration of a product's components. Some industries, such as semiconductor and steel manufacturers use the term *fabrication* instead.

The manufacturing sector is closely connected with engineering and industrial design. Examples of major manufacturers in the North America include General Motors Corporation, General Electric, and Pfizer. Examples in Europe include Volkswagen

Group, Siemens, and Michelin. Examples in Asia include Toyota, Samsung, and Bridgestone.

History and development

- In its earliest form, manufacturing was usually carried out by a single skilled artisan with assistants. Training was by apprenticeship. In much of the pre-industrial world the guild system protected the privileges and trade secrets of urban artisans.
- Before the Industrial Revolution, most manufacturing occurred in rural areas, where household-based manufacturing served as a supplemental subsistence strategy to agriculture (and continues to do so in places). Entrepreneurs organized a number of manufacturing households into a single enterprise through the putting-out system.
- Toil manufacturing is an arrangement whereby a first firm with specialized equipment processes raw materials or semi-finished goods for a second firm.

Manufacturing systems: The changing methods of manufacturing

- Craft or Guild system
- Putting-out system
- English system of manufacturing
- American system of manufacturing
- Soviet collectivism in manufacturing
- Mass production
- Just In Time manufacturing
- Lean manufacturing
- Flexible manufacturing
- Mass customization
- Agile manufacturing
- Rapid manufacturing
- Prefabrication
- Packaging and labeling
- Ownership
- Fabrication
- Publication

Economics of manufacturing

According to some economists, manufacturing is a wealth-producing sector of an economy, whereas a service sector tends to be wealth-consuming. Emerging technologies have provided some new growth in advanced manufacturing employment opportunities in the Manufacturing Belt in the United States. Manufacturing provides important material support for national infrastructure and for national defense.

On the other hand, most manufacturing may involve significant social and environmental costs. The clean-up costs of hazardous waste, for example, may outweigh the benefits of a product that creates it. Hazardous materials may expose workers to health risks. Developed countries regulate manufacturing activity with labor laws and environmental laws. In the U.S, manufacturers are subject to regulations by the Occupational Safety and Health Administration and the United States Environmental Protection Agency. In Europe, pollution taxes to offset environmental costs are another form of regulation on manufacturing activity. Labor Unions and craft guilds have played a historic role in the negotiation of worker rights and wages. Environment laws and labor protections that are available in developed nations may not be available in the third world. Tort law and product liability impose additional costs on manufacturing.

Manufacturing requires huge amounts of fossil fuels. The construction of a single car in the United States requires, on average, at least 20 barrels of oil.

Manufacturing and investment around the world

Surveys and analyses of trends and issues in manufacturing and investment around the world focus on such things as:

- the nature and sources of the considerable variations that occur cross-nationally in levels of manufacturing and wider industrial-economic growth;
- competitiveness; and
- attractiveness to foreign direct investors.

In addition to general overviews, researchers have examined the features and factors affecting particular key aspects of manufacturing development. They have compared production and investment in a range of Western and non-Western countries and presented case studies of growth and performance in important individual industries and market-economic sectors.

On June 26, 2009, Jeff Immelt, the CEO of General Electric, called for the United States to increase its manufacturing base employment to 20% of the workforce, commenting that the U.S. has outsourced too much in some areas and can no longer rely on the financial sector and consumer spending to drive demand. A total of 3.2 million – one in six U.S. manufacturing jobs – have disappeared between 2000 and 2007.

Manufacturing resource planning

Manufacturing resource planning (**MRP II**) is defined by APICS as a method for the effective planning of all resources of a manufacturing company. Ideally, it addresses

operational planning in units, financial planning in dollars, and has a simulation capability to answer "what-if" questions and extension of closed-loop MRP.

This is not exclusively a software function, but a marriage of people skills, dedication to data base accuracy, and computer resources. It is a total company management concept for using human resources more productively.

Key functions and features

MRP II is not a proprietary software system and can thus take many forms. It is almost impossible to visualize an MRP II system that does not use a computer, but an MRP II system can be based on either purchased–licensed or in-house software.

Almost every MRP II system is modular in construction. Characteristic basic modules in an MRP II system are:

- Master production schedule (MPS)
- Item master data (technical data)
- Bill of materials (BOM) (technical data)
- Production resources data (manufacturing technical data)
- Inventories and orders (inventory control)
- Purchasing management
- Material requirements planning (MRP)
- Shop floor control (SFC)
- Capacity planning or capacity requirements planning (CRP)
- Standard costing (cost control)
- Cost reporting / management (cost control)

together with auxiliary systems such as:

- Business planning
- Lot traceability
- Contract management
- Tool management
- Engineering change control
- Configuration management
- Shop floor data collection
- Sales analysis and forecasting
- Finite capacity scheduling (FCS)

and related systems such as:

- General ledger
- Accounts payable (purchase ledger)
- Accounts receivable (sales ledger)
- Sales order management

- Distribution requirements planning (DRP)
- Automated warehouse management
- Project management
- Technical records
- Estimating
- Computer-aided design/computer-aided manufacturing (CAD/CAM)
- CAPP

The MRP II system integrates these modules together so that they use common data and freely exchange information, in a model of how a manufacturing enterprise should and can operate. The MRP II approach is therefore very different from the "point solution" approach, where individual systems are deployed to help a company plan, control or manage a specific activity. MRP II is by definition fully integrated or at least fully interfaced.

Industry specifics

MRP II systems have been implemented in most manufacturing industries. Some industries need specialised functions e.g. lot traceability in regulated manufacturing such as pharmaceuticals or food. Other industries can afford to disregard facilities required by others e.g. the tableware industry has few starting materials – mainly clay – and does not need complex materials planning. Capacity planning is the key to success in this as in many industries, and it is in those that MRP II is less appropriate.

MRP and MRPII: History and evolution

Material requirements planning (MRP) and manufacturing resource planning (MRPII) are predecessors of enterprise resource planning (ERP), a business information integration system. The development of these manufacturing coordination and integration methods and tools made today's ERP systems possible. Both MRP and MRPII are still widely used, independently and as modules of more comprehensive ERP systems, but the original vision of integrated information systems as we know them today began with the development of MRP and MRPII in manufacturing.

The vision for MRP and MRPII was to centralize and integrate business information in a way that would facilitate decision making for production line managers and increase the efficiency of the production line overall. In the 1980s, manufacturers developed systems for calculating the resource requirements of a production run based on sales forecasts. In order to calculate the raw materials needed to produce products and to schedule the purchase of those materials along with the machine and labor time needed, production managers recognized that they would need to use computer and software technology to manage the information. Originally, manufacturing operations built custom software programs that ran on mainframes.

Material requirements planning (MRP) was an early iteration of the integrated information systems vision. MRP information systems helped managers determine the

quantity and timing of raw materials purchases. Information systems that would assist managers with other parts of the manufacturing process, MRPII, followed. While MRP was primarily concerned with materials, MRPII was concerned with the integration of all aspects of the manufacturing process, including materials, finance and human relations.

Like today's ERP systems, MRPII was designed to integrate a lot of information by way of a centralized database. However, the hardware, software, and relational database technology of the 1980s was not advanced enough to provide the speed and capacity to run these systems in real-time, and the cost of these systems was prohibitive for most businesses. Nonetheless, the vision had been established, and shifts in the underlying business processes along with rapid advances in technology led to the more affordable enterprise and application integration systems that big businesses and many medium and smaller businesses use today (Monk and Wagner).

MRP and MRPII: General concepts

Material requirements planning (MRP) and manufacturing resource planning (MRPII) are both incremental information integration business process strategies that are implemented using hardware and modular software applications linked to a central database that stores and delivers business data and information.

MRP is concerned primarily with manufacturing materials while MRPII is concerned with the coordination of the entire manufacturing production, including materials, finance, and human relations. The goal of MRPII is to provide consistent data to all players in the manufacturing process as the product moves through the production line.

Paper-based information systems and non-integrated computer systems that provide paper or disk outputs result in many information errors, including missing data, redundant data, numerical errors that result from being incorrectly keyed into the system, incorrect calculations based on numerical errors, and bad decisions based on incorrect or old data. In addition, some data is unreliable in non-integrated systems because the same data is categorized differently in the individual databases used by different functional areas.

MRPII systems begin with MRP, material requirements planning. MRP allows for the input of sales forecasts from sales and marketing. These forecasts determine the raw materials demand. MRP and MRPII systems draw on a master production schedule, the break down of specific plans for each product on a line. While MRP allows for the coordination of raw materials purchasing, MRPII facilitates the development of a detailed production schedule that accounts for machine and labor capacity, scheduling the production runs according to the arrival of materials. An MRPII output is a final labor and machine schedule. Data about the cost of production, including machine time, labor time and materials used, as well as final production numbers, is provided from the MRPII system to accounting and finance (Monk and Wagner).

Benefits

MRP II systems can provide:

- Better control of inventories
- Improved scheduling
- Productive relationships with suppliers

For design / engineering:

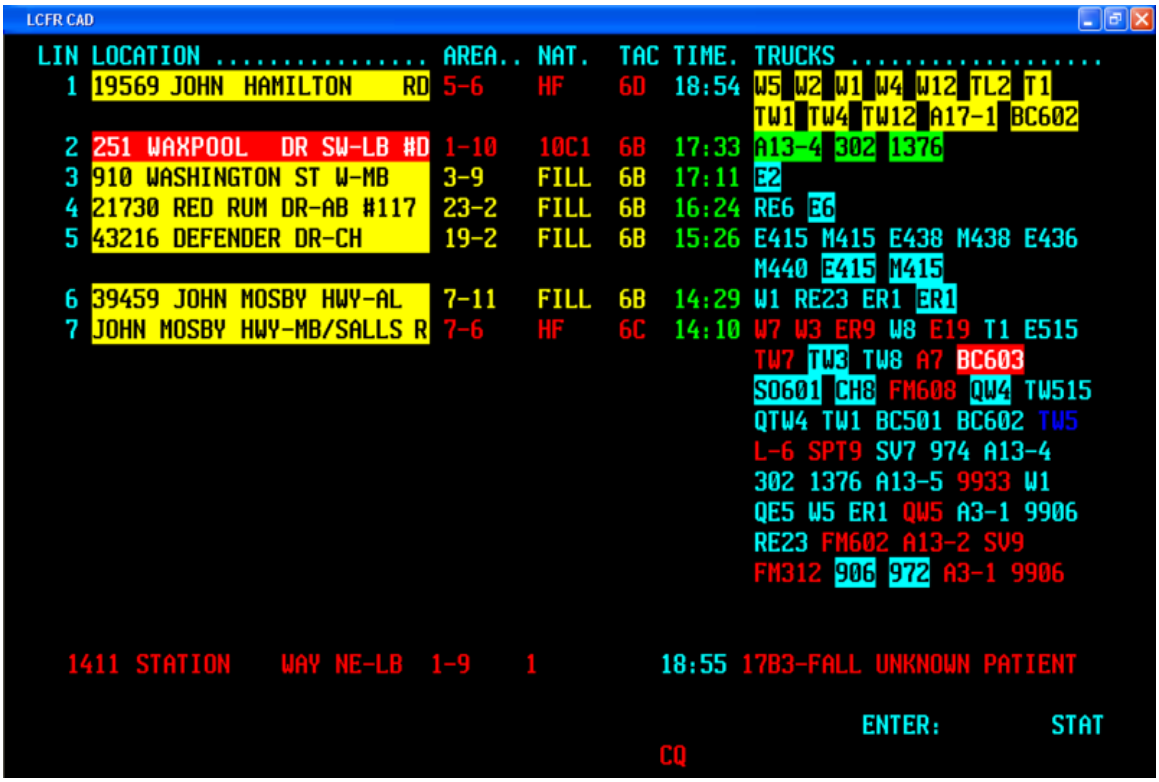
- Improved design control
- Better quality and quality control

For financial and costing:

- Reduced working capital for inventory
- Improved cash flow through quicker deliveries
- Accurate inventory records

Chapter-11

Computer-aided Dispatch



The CAD system of a fire department on a busy day. The line at the bottom is about to be dispatched. (Note:addresses have been changed for privacy reasons.)

Computer-assisted dispatch, also called **Computer Aided Dispatch** (CAD), is a method of dispatching taxicabs, couriers, field service technicians, or emergency services assisted by computer. It can either be used to send messages to the dispatchee via a mobile data terminal (MDT) and/or used to store and retrieve data (i.e. radio logs, field interviews, client information, schedules, etc.). A dispatcher may announce the call details to field units over a two-way radio. Some systems communicate using a two-way radio system's selective calling features. CAD systems may send text messages with call-for-service details to alphanumeric pagers or wireless telephony text services like SMS. The central

idea is that persons in a dispatch center are able to easily view and understand the status of all units being dispatched. CAD provides displays and tools so that the dispatcher has an opportunity to handle calls-for-service as efficiently as possible.

CAD typically consists of a suite of software packages used to initiate public safety calls for service, dispatch, and maintain the status of responding resources in the field. It is generally used by emergency communications dispatchers, call-takers, and 911 operators in centralized, public-safety call centers, as well as by field personnel utilizing mobile data terminals (MDTs) or mobile data computers (MDCs).

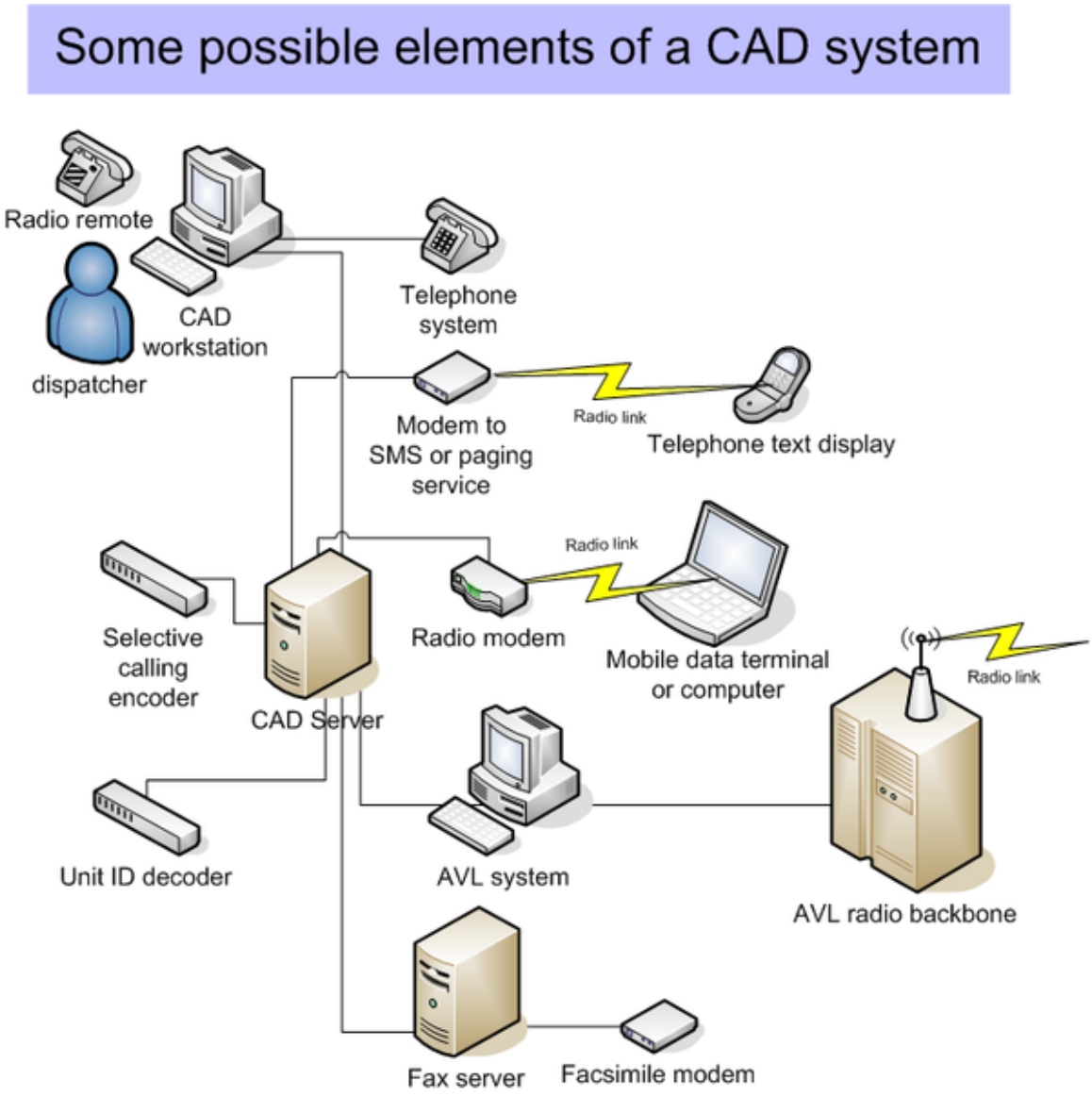
CAD systems consist of several modules that provide services at multiple levels in a dispatch center and in the field of public safety. These services include call input, call dispatching, call status maintenance, event notes, field unit status and tracking, and call resolution and disposition. CAD systems also include interfaces that permit the software to provide services to dispatchers, calltakers, and field personnel with respect to control and use of analog radio and telephony equipment, as well as logger-recorder functions.

Manual dispatching

Computer-assisted dispatching improves the efficiency and accuracy of each step of the manual process:

- The call taker records the details on a paper card and offers advice to the caller.
- The paper card is passed by hand or sent on a conveyor belt or pneumatic tube to the dispatcher.
- The dispatcher allocates the task to one or more available mobile units depending on each units capability and location.
- The dispatcher passes the details of the task to the mobile unit by reading the details over two-way radio or telephone.
- The mobile unit advises the dispatcher of their progress through the task till its completion which are recorded on a paper log.
- Paper logs can be reviewed afterwards for accounting for services and investigating problems with service delivery.

Methodology



CAD systems may be interconnected with automatic vehicle location systems, mobile data terminals, office telephones, and selective calling and push-to-talk ID.

Computer-assisted dispatch systems use one or more servers located in a central dispatch office, which communicate with computer terminals in a Communications Center or with mobile data terminals installed police vehicles. There are a multitude of CAD programs that suit different department needs, but the fundamentals of each system are the same. They include:

- Log On/Off times of Police Personnel (sworn/non-sworn)
- Generating and archiving incidents that begin with a phone call from a citizen or originate from personnel in the field
- Assigning field personnel to incidents

- Updating Incidents and logging those updates
- Generating Case Numbers for incidents that require an investigation
- Timestamping every action taken by the dispatcher at the terminal

In an ideal setting, a call is received by a call-taker and information about the call is inputted into the CAD template. Simply, Location, Reporting Party and Incident are the main fields that have to be populated by type-codes. For example, if there was a Burglary in progress, the type-code for that Incident could be "BURG"; when BURG is typed out, then the program will spell out "BURGLARY (in progress)". If the Location was at the 1400 block of Madison, the type-code could be "14MAD." The Reporting Party information would be populated by the call-taker including Last Name, First Name, Call-Back number, etc.

A typical CAD printout looks something like this based on the example above:

```
-----------------------------------
LOCATION - 1400 Madison
RP       - Doe, John, 555-5555, 1404 Madison
INCIDENT - BURGLARY (in progress)
SYNOPSIS - "Caller reports a possible burglary in progress based on
seeing individuals
inside the residence/Caller advises 2 persons inside the location and
call advises
the current residents are on vacation."
-----------------------------------
```

Again, granted as it can be seen that the fields are spelled out, the call-taker uses those abbreviations that are already predetermined in order to quickly gather and transmit the information.

The dispatcher then receives the call from the call-taker and is able dispatch the call to those available. The dispatcher's screen would show the available personnel that are dispatchable. A typical setting can be exemplified by this:

```
-----------------------------------
INCIDENT # - 554123
LOCATION   - 1400 Madison
RP         - Doe, John, 555-5555
INCIDENT   - BURGLARY (In Progress)
SYNOPSIS   - "Caller reports a possible burglary in progress based on
seeing individuals
inside the residence/Caller advises 2 persons inside the location and
call advises
the current residents are on vacation."
UNITS      - 746 (Pri), 749 (Cov)
-----------------------------------
Units available      - (3)
Units out of service - (2)

745 - Avail.
746 - Not Avail. Inc # 554121
```

```
747 - Avail.
748 - Avail.
749 - Not Avail. Inc # 554122
-----------------------------------
```

Everything that is gathered, dispatched and disposed is usually stored in a central server where the type codes reside in, or possibly another server. All of these calls which have incident numbers attached to them can be recalled by an internal search engine. For example, a request for a printout of all calls to Madison in the past hour could be gathered by querying the CAD program by Location:

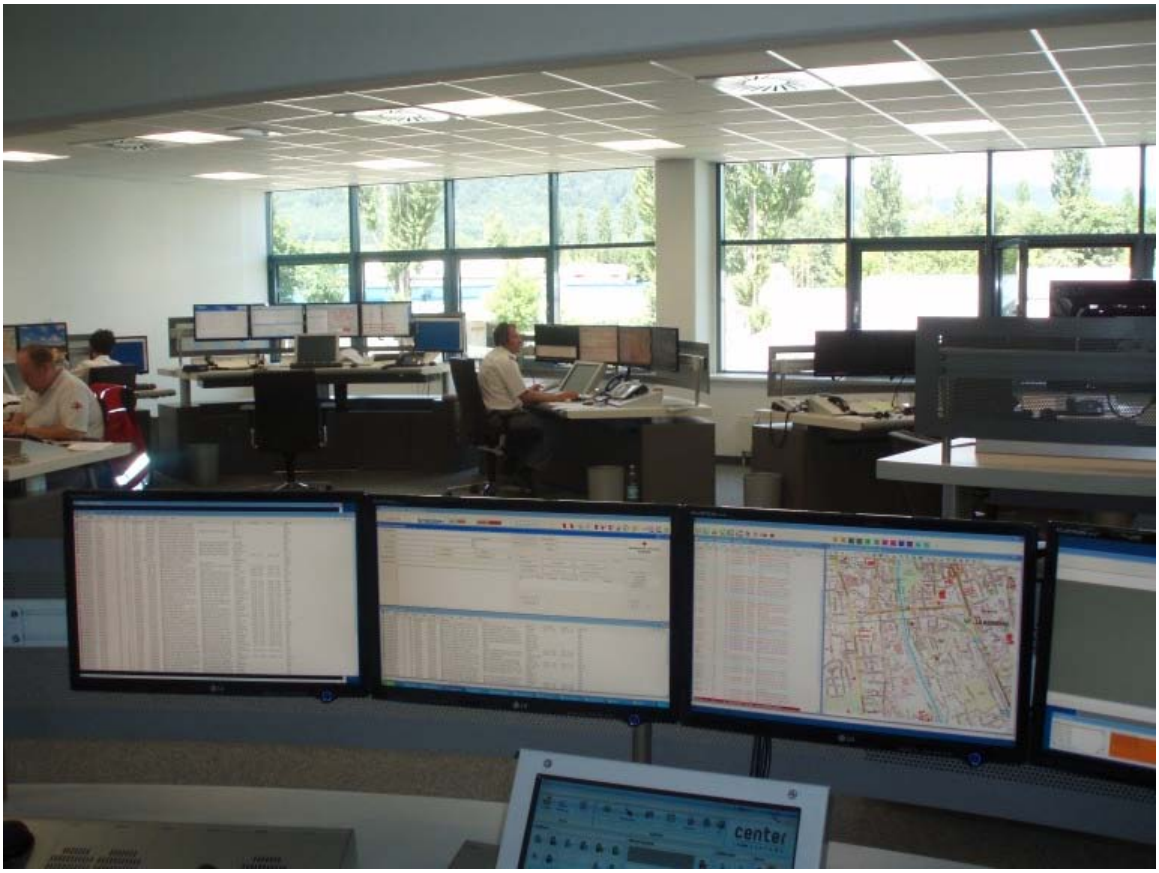
```
Search by: Location
LOCATION [          ]
---
Result:

(Now filled in)

Search by: Location
LOCATION [14MAD     ]
---
Result: (1) Incidents
```

CAD can be used in a multitude of ways, whether it is for radio logs, call logs or statistical analysis.

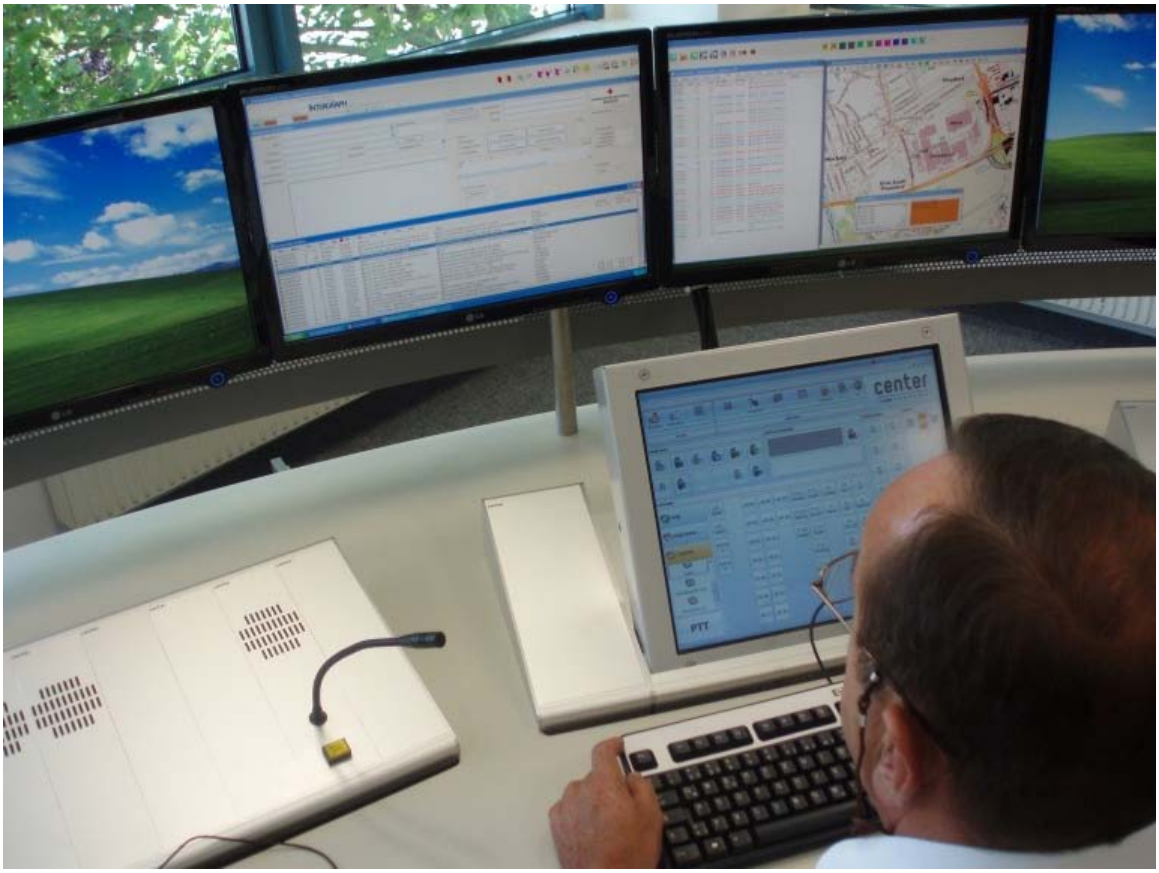
Consoles

A dispatch facility used by Denver RTD features Motorola Centracom radio communication consoles and a GPS-based AVL system. Left picture is dispatcher console position. Right picture is supervisor's console. At right is a drawing showing basic controls for a single channel.

Typical of local government dispatching facilities, the Denver RTD's facility is one example of a transit dispatch center. Communications consoles are mounted in desk-style electronics racks. Features include multi-line telephones. Modern facilities usually include a variety of computing systems for operational and administrative purposes.



Ambulance Dispatch Center Austria



Console with CAD and Voice Switch

Consoles serve as a human interface and connect to push-to-talk dispatch radio systems. Audio from all channels is processed through audio level compression circuits and is routed to two separate speakers identified as *select* and *unselect*. Each has a volume control. The select channel or channels carry the highest priority communications. To prevent missed messages on critical channels, the select volume may be configured so it cannot be set to an inaudible level. Unselect channels may be used for special events, other agencies, or purposes that do not involve dispatch and may be inaudible. By pressing a button, any channel on the console can be toggled between select and unselect status. Each channel has an independent push-to-talk button, allowing the dispatcher to talk over one channel at a time. For broadcast messages, a single button transmits over all selected channels at the same time. A digital clock and an LED bar-graph VU meter are included.

Each channel has a label identifying it and indicator lights and buttons to control settings. A typical channel has a busy light, a call light, select light, select button, and a transmit button. The steady, red busy light indicates another dispatch position is transmitting on the channel. The flashing yellow call light indicates a field unit is talking on the channel. The call light usually blinks for several seconds after a transmission ends allowing a busy dispatcher to look up from a telephone call and determine which channel the last message came from.

Some console dispatch panels are actually a PC based application. Such is the case of Zetron's Acom system and Avtec's Scout system. This allows for easy customization and modification of the dispatch key layout.

Service levels and geographic information

Computerized mapping, Automatic vehicle location, Automatic number identification and caller-identification technology are often used to enhance the service by pinpointing the locations of both the client and the most suitable vehicle for serving the client.

Some CAD systems allow several sources of information to be combined. For example, adding automatic vehicle location (AVL) and geographic information (GIS) could improve service by getting units to a service call location faster. Ideally, CAD is connected to monitor vehicle locations provided by an AVL system. This information is used to suggest the closest vehicle to an event. How is the closest unit determined?

Basic zone system

The simplest system is a beat or zone map system. For example, in a community with four fire stations, a grid is overlaid on a community map. Each zone of the grid is identified with a progression of police beats, ambulance zones, transit zones, or fire stations. One grid might be labeled: AB241. This means fire station 2, then 4, then 1, then 3 would respond to a fire call occurring inside this zone. The predefined order is created by persons with expertise in the service being provided, local geography, traffic, and patterns in calls for service.

Since only basic GIS information is included, if AVL was available, it would simply display service vehicle locations on a map. The closest unit would be interpreted by the dispatcher looking at vehicle locations projected on the map.

Where detailed geographic data are not available, units may be assigned based on the center of a district. To make the computing problem easier, the CAD system may use *centroids* to evaluate service vehicle locations. Centroids are estimated center points within a zone. The system calculates a distance from a fire station or AVL location to a centroid point. The closest fire station, according to CAD system rules, would be assigned. Systems may use centroids that are not exactly centered in order to skew or weight system decisions. Staff based at a fire station that is physically closer by drawing a straight line on the map may be slower to reach a zone. This can occur because responding units must drive around freeways, lakes, or terrain obstructions in order to reach a zone. A centroid may be moved because 200-car freight trains often block a railroad crossing used to access a particular zone.

This is the cheapest system to develop because it requires the least detailed geographic information and the simplest calculations. Another problem occurs where several services use the same system. Police and transit, for example, may have different ideas about what boundaries define the ideal zone or how centroids should be weighted.

CAD using geocoding

Geocoding is a translation system allowing addresses to be converted to X- and Y-coordinates. Someone placing a call for service has an address attached to a wired phone number or tells the dispatcher their address. For example, suppose the caller's address is *123 Main Street*.

The GIS or CAD system includes a look-up table. The table may identify odd-numbered addresses in the community as being on the north and east sides of streets. Addresses from 113 to 157 Main Street are identified as being along Main Street's center line between Broadway and Washington. 123 is estimated to be on the north side of Main Street somewhere closer to 113 than 157. This estimate produces a latitude and longitude, or a set of Universal Transverse Mercator coordinates. The coordinates are close enough to identify the closest service vehicle. This system may automatically append the name of the nearest cross-street or intersecting street.

Again, the system uses a straight-line distance to determine which service vehicle is closest to a call for service. If an AVL system is used, the CAD will look through a list of most recent reported vehicle positions. Next, the positions are compared to the service vehicle status. The CAD system may identify several of the closest units that have a status of *available*. The dispatcher makes an ideal choice from the CAD system shortlist.

This type of system is significantly more expensive than a zone system. The basic system may start with maps from the US Census Bureau or a county assessor's office. The quality of these maps may be good but will not be ideal for dispatching. There would normally be one or more persons on staff who would deal with data changes from new development, new streets, or data quality problems. The person would compile addresses and generate street centerlines in mapping software. Geocoding varies in accuracy depending on data sources and vendors. It normally takes years of work and planning before a system is implemented. Modern geocoded systems will often display service vehicle locations, the location of service calls, and the locations of callers on a map. This helps to disambiguate calls for service and reduces the likelihood of dispatching two reports of a single call for service as two separate calls.

Another problem comes from technologies using differing datums or coordinate systems. For example, suppose your AVL system uses degrees-decimal degrees format. The AVL display for a vehicle at the Heart Butte Post Office in Montana shows a latitude and longitude of 48.28333 N, -112.83583 W. The CAD system uses degrees-minutes-seconds format data and shows the same location as 481700N, 1125009W. How do you translate? This is sometimes a problem with neighboring CAD systems. Ideally, you should be able to send and receive calls to and from CAD systems in neighboring areas. What if the state or provincial government has standardized on a different coordinate system?

Full GIS/AVL integration

The most expensive and technically-challenging systems fully utilize the capabilities of GIS and AVL. In these systems, the street centerlines are described as *routable*. In addition to geocoding and accurate street centerlines, intersections have attributes or scores. Can a service vehicle turn left from eastbound Carnegie Street onto northbound Hooligan Boulevard? A scoring system is used to assess the difficulty of making the turn. At one end of the scoring system there might be an interchange where service vehicles had unrestricted access in making the turn. Perhaps both streets are one-way, making it relatively easy to turn from one onto another. In the middle scores, a left turn might be blocked occasionally by heavy traffic, a draw bridge, or street cars. At the most difficult score, the two streets may cross but the lack of any interchange does not allow service vehicles to get from one to the other.

To calculate the closest service vehicles, the CAD system does a network analysis of the road system based on these routable street centerlines. It assesses the path from the service call to the AVL location of available vehicles. The system recommends the service vehicles with the shortest path.

Routable street centerlines take into account differences between northbound and southbound lanes on a freeway or turnpike. For example, to reach a point in the southbound lanes of a turnpike, service vehicles may need to drive north to the next exit then return on the southbound side. The analysis of a routable street network takes this into account so long as the event location is accurately reported. Routable systems account for barriers like lakes by calculating the distance of the driven route rather than a straight line distance. It is assumed the service vehicle driver knows the shortest path or that all drivers make similar numbers of wrong turns.

Concentration

CAD systems require support staff with special skills. This can lead to concentration of dispatch facilities, particularly where there is population growth or where automation is required to meet defined service objectives.

In any system, concentration of facilities increases risks of outages or massive failures. In a system where the call traffic is so high that advanced technology is needed to handle routine levels of day-to-day calls, relatively minor failures can have major effects on service levels. For example, where everyone is used to the convenience of AVL, an AVL outage can suddenly increase staff workloads. Suppose a failure causes a condition where CAD cannot recommend a closest unit. How will the dispatcher efficiently assess which unit to assign?

Data management problem

Data quality and data management are significant issues in every system. Part of managing the problem is to establish and enforce standards for data.

Staffing will periodically change as people retire or are promoted. One staff member entered street names, "McDonald" while others enter the same street "Mc Donald." When a complaint-taker is typing a street name into the CAD system, these will sort differently:

- Mc Donald Av
- Mc Intosh Av
- Mc Gulliver Wy
- Mc Zzyrx Rd
- McDonald Av

How will quality standards be implemented to prevent mis-sorted type-ahead feature entries?

Disambiguation can be a problem in cases, for example, where a service area has two Main Streets. In large service areas it is normal to have dozens to hundreds of duplicated and similar street names. The problem can be complicated if the person requesting service is not calling from a wired phone and their location is unclear. Some long streets may have identical address ranges in each city along their route. The caller is in front of 2200 Main Street, but which one? How will the decision-making process be reinforced by good data quality?

Systems require perpetual software upgrades each of which may normalize data differently. Or, a different company may win the low bid next time a system is replaced. Imagine taking a file of 270,000 addresses that took a staff ten years to compile and feeding them through a parsing filter to split street, drive, or road, from each record. Imagine a new system stores apartment and suite letters, (2200 A Main Street) in separate fields and you are responsible for the conversion.

Data exchange (EDI)

In public safety systems, standards are under discussion to allow disparate systems to exchange call information. For example, a call taker at the county fire department receives a call for an auto accident inside a city limit. Evolving standards will allow CAD systems to send messages to one another for calls originating outside local jurisdiction. Some entities have arrangements that already support data exchange between systems, but standards aim to make these interconnections more common. Because of auditing trail and fail-safe needs, the problem is more complex than it sounds.

The usage of EDI applied to CAD is specific to the law enforcement community and should not be confused with Electronic Document Interchange (EDI) standards for eCommerce. Within law enforcement EDI is used as a buzzword to represent all electronic automated messaging.

More mature efforts to interconnect CAD can be found in the standards developed for the Intelligent Transportation Initiatives program of Department of Transportation This initiative sponsored the IEEE 1512 series of protocols for emergency management which

provides sophisticated means to coordinate incidents across operations centers using CAD software.

Additional work is occurring under the National Information Exchange Model to link homeland security with CAD. Also the OASIS international standards body has produced standards funded in part by the DHS and the disaster management e-gov initiative to communicate in emergencies.

Other interoperability technologies can bridge disparities between the data-format, software, and hardware that constitute various computer-aided dispatch systems in various jurisdictions. *Middleware*, software and servers (data brokers), can translate and integrate various systems into a seamless automated dispatch system. One example of such middleware (provided by Utah-based) exists in Orange County, Calif., where the Fire Authority has integrated different emergency service answering points into a seamless dispatching network. A similar project was completed for the Silicon Valley Regional Interoperability Project (SVRIP), and is part of the Dept. of Homeland Security's CADIP report.

Part of business enterprise computing system

In business use of CAD, the dispatch system may be a module or part of a larger enterprise computing system. Rather than having multiple infrastructure's, being able to have a single infrastructure with many applications running on it is important.

At the high end of enterprise integration for CAD there is SOS. SOS or Systems of Systems is a methodology and a set of technology for linking distributed independent applications into one meta-system or system of systems. These methods were originally being used at DOD for command and control (C2) but have now been applied to dispatch in efforts like the Department of Transportation Intelligent Transportation System at the Transportation Management Centers and other efforts involving DHS counterterrorism or fusion centers. Some local jurisdictions have also integrated their dispatch systems using EAI (Electronic Application Integration) software.

Recent developments

Computer aided call handling (CACH) is built on the premise that effective call handling is the foundation for an efficient dispatch response. By using structured call handling and a series of risk calculations, such systems can make objective dispatch recommendations based on information provided by the caller.

Chapter-12

Cold Chain

Vaccines are temperature controlled until use

Slurry ice used to ship sensitive food products

Truck with cooling system

Iced seafood on display

A **cold chain** is a temperature-controlled supply chain. An unbroken cold chain is an uninterrupted series of storage and distribution activities which maintain a given temperature range. It is used to help extend and ensure the shelf life of products such as fresh agricultural produce, frozen food, photographic film, chemicals and pharmaceutical drugs.

Uses

Cold chains are common in the food and pharmaceutical industries and also some chemical shipments. One common temperature range for a cold chain in pharmaceutical

industries is 2 to 8 °C. but the specific temperature (and **time** at temperature) tolerances depend on the actual product being shipped.

This is important in the supply of vaccines to distant clinics in hot climates served by poorly developed transport networks. Disruption of a cold chain due to war may produce consequences similar to the Smallpox outbreaks in the Philippines during the Spanish-American war.

Traditionally all historical stability data developed for vaccines was based on the temperature range of 2-8 °C. With recent development of biological products by former vaccine developers, biologics has fallen into the same category of storage at 2-8 °C due to the nature of the products and the lack of testing these products at wider storage conditions.

The cold chain distribution process is an extension of the good manufacturing practice (GMP) environment that all drugs and biological products are required to adhere to, enforced by the various health regulatory bodies. As such, the distribution process must be validated to ensure that there is no negative impact to the safety, efficacy or quality of the drug substance. The GMP environment requires that all processes that might impact the safety, efficacy or quality of the drug substance must be validated, including storage and distribution of the drug substance.

Validation

A cold chain can be managed by a quality management system. It should be analyzed, measured, controlled, documented, and validated.

The food industry uses the process of Hazard Analysis and Critical Control Point, HACCP, as a useful tool. Its usage continues into other fields. PDA (Parenteral Drug Association) Technical Report # 39 gives a rough summary of how the cold chain can be validated.

The overall approach to validation of a distribution process is by building more and more qualifications on top of each other to get to a validated state. This is done by executing a Component Qualification on the packaging components. Next, an Operational Qualification that demonstrates the process performs at the operational extremes. The final piece is the Performance Qualification that demonstrates that what happens in the real world is within the limits of what was demonstrated in the Operational Qualification limits.

The PDA's Technical Report states that a Component Qualification is required to demonstrate that a component can be manufactured to the design criteria of that individual component. This was put into the document because the industry did not understand the principles of Validation; all Validation processes were specific to equipment and not auxiliary processes such as shipping/distribution.

Performing thermal testing can also help with validating the cold chain. Certified test labs use environmental chambers to simulate ambient profiles that a package may encounter in the distribution cycle. Thermocouple probes and separate temperature dataloggers measure temperatures within the product load to determine the response of the package to the test conditions. Replicate testing based on a qualification protocols is used to create a final qualification report that can be used to defend the configuration when audited by regulators. It is normally best to have an individual that understands the principles of Validation, when defending such processes to a Federal Regulatory body of any nation.

Cold chains need to be evaluated and controlled:

- Carriers and logistics providers can assist shippers. These providers have the technical ability to link with airlines for real time status, generate web-based export documentation and provide electronic tracking.
- The use of refrigerator trucks, refrigerator cars, reefer ships, reefer containers, and refrigerated warehouses is common.
- Shipment in insulated shipping containers or other specialised packaging.
- Temperature data loggers and RFID tags help monitor the temperature history of the truck, warehouse, etc. and the temperature history of the product being shipped. They also can help determine the remaining shelf life.
- Documentation is critical. Each step of the custody chain needs to follow established protocols and to maintain proper records. Customs delays occur due to inaccurate or incomplete customs paperwork, so basic guidelines for creating a commercial invoice should be followed to ensure the proper verbiage, number of copies, and other details.

During the distribution process one should monitor that process until one builds a sufficient data set that clearly demonstrates the process is in compliance and in a state of control. Each time the process does not conform to the process, the event should be properly documented, investigated and corrected so that the temperature excursion do not occur on future shipments. Thus the process is continually evolving and correcting for anomalies that occur in the process. Eventually the process can evolve into periodic monitoring once sufficient data demonstrates that the process is in a state of control. Any anomaly that occurs once a process is in a state of control will result in the process being invalidated and not in control and result in product withdraw from the market to ensure patient safety.

It is necessary to develop an internal documentation system as well as multi-party communication standards and protocols to transfer or create a central repository or hub to track information across the supply chain. These systems would monitor equipment status, product temperature history, and custody chain, etc. These help ensure that a food, pharmaceutical, or vaccine is safe and effective when reaching its intended consumer.

Chapter-13

Dispatch (logistics)

Dispatch is a procedure for assigning employees (workers) or vehicles to customers. Industries that dispatch include taxicabs, couriers, emergency services, as well as home and commercial services such as maid services, plumbing, HVAC, pest control and electricians.

With vehicle dispatching, clients are matched to vehicles according to the order in which clients called and the proximity of vehicles to each client's pick-up location. Telephone operators take calls from clients, then either enter the client's information into a computer or write it down and give it to a dispatcher. In some cases, calls may be assigned a priority by the call-taker. Priority calls may jump the queue of pending calls. In the first scenario, a central computer then communicates with the mobile data terminal located in each vehicle in the second, the dispatcher communicates with the driver of each vehicle via two-way radio.

With home or commercial service dispatching, customers usually schedule services in advance and the dispatching occurs the morning of the scheduled service. Depending on the type of service, workers are dispatched individually or in teams of 2 or more. Dispatchers have to coordinate worker availability, skill, travel time and availability of parts. The skills required of a dispatcher are greatly enhanced with the use of computer dispatching software.

Manual dispatch systems

The following are examples of manual systems used to track the status of resources in a dispatched fleet.

Cards

Card systems employ a set of shelves with a slot for each unit in the dispatch fleet. Each vehicle or resource has a slot in the shelving system. In it, a card, like a time card used to track an employee's work hours, is stored. A time clock, similar to the one that stamps work hours on a time card, is used to stamp event times on each card. At the beginning of

a work day, the resource's identifier or other information is handwritten on the card. Each time the resource's status changes, the card is punched in the time clock and a new status entry is handwritten on the card. The card collects a series of entries through the work shift.

In a tow truck example, the card might be labeled with the tow car's radio identifier, "Downtown 6" and may be labeled with the vehicle number or data about the capabilities of the specific tow car. It might give a weight capacity, show the unit as a flat bed or cradle snatcher, or mention the unit carries a can of Diesel fuel. The name of the staff on the car might be noted. At the start of a shift, the dispatcher would note the unit "available" and time stamp the card. At the assignment to a call, the call information would be written on the card and the card might be stamped at the moment the assignment is read to the tow car crew. The string of notes and time stamps allows dispatch staff to get a clear picture of the status of a small fleet.

Some systems use shelving with red and green lights and a switch at the back of the card slot. If the resource's card is pushed all the way into the card slot, the switch is actuated and an indicator lamp turns red. This identifies the tow car whose card occupies that slot as not available or assigned to a call. Leaving the card pulled partway out leaves the indicator green, showing the dispatcher that unit is available. Is anyone available? The lights are supposed to give the dispatch staff a snapshot of their resource situation.

A major flaw of this system is that cards are inside shelves and trying to look at an entire set of cards to evaluate the overall situation requires the dispatcher to pull out every card, one at a time, and read it. If two or more resources are sent to the same call, the dispatcher has a lot of writing to do.

Punched tags

Punched tag systems employ a set of pegs with each peg holding tags for one unit in the dispatch fleet. Each vehicle working the current shift has a peg with a tag describing the unit's current status. A time clock, similar to the one that stamps work hours on a time card, is used to stamp times on each tag. At the beginning of a work day, the resource's identifier may be posted above the peg. The unit's start time is stamped and their status is written on the tag. Each time the resource's status changes, a new tag is written and the tag is time stamped in order to log the time the unit's status changed. The peg collects a stack of tags through the work shift.

In a tow truck example, the peg might be labeled with the tow car's radio identifier, "Downtown 6" and may be labeled with the vehicle number or data about the capabilities of the specific tow car. It might give a weight capacity, show the unit as a flat bed or cradle snatcher, or mention the unit carries a can of Diesel fuel. The name of the staff on the tow car might be noted. At the start of a shift, the dispatcher would note the unit "available" and time stamp a tag, then hang it on that unit's peg. At the assignment to a call, the call information would be written on another tag and the tag might be stamped at the moment the assignment is read to the tow car crew. The tag would then be hung on

that unit's peg. The stack of tags allows dispatch staff to get a clear picture of the status of a small fleet.

Some systems use colored tags to show general categories of events such as "available". For example, each unit that is available might have the fact noted on an orange tag. Is anyone available? A glance at the pegboard shows anybody whose tag is "orange" is available. An repossession might use a yellow tag to identify a service call with a safety issue where the police should be called in the event the tow car crew doesn't check in by radio within five minutes. A blue tag might show a resource is taking a dinner or lunch break.

A major flaw of this system is that tags can easily be posted on the wrong peg, causing confusion. This can be countered by writing unit identifiers on every tag: a lot of work. In colored-tag systems, it's always possible to run out of certain colors of tags, messing up the system. If two or more resources are sent to the same call, the dispatcher has a lot of writing to do.

Plastic icons

In a plastic icon system, the blank panel on the communications console or a nearby wall is fitted with a sheet of Velcro. The material has vertical stripes painted on it, making a column for each of several possible status conditions. The simplest system is two columns: available and unavailable. Magnetized icons can be used in place of Velcro. The icons can be colored or shaped to identify the type of unit or some other feature of the resource.

Each vehicle working the current shift has an icon placed in the column describing the unit's current status. A log book is used to track times, event details, and other information about calls for service. In a tow truck example, the icon might be labeled with the tow car's radio identifier, "Downtown 6". During a shift, the icon would be moved by the dispatcher into whatever column describes the resource's current condition. Alternatively, there could be columns for some other condition such as the names of move-up or standby points where resources are sent to backfill for busy tow cars.

A major flaw of this system is that icons can easily be misplaced or fall off of the status board. Magnetic objects can damage cathode ray tube displays if they get too close to the display face or housing.

Airline dispatch

In airline operations in a few countries, a dispatcher shares legal responsibility for a flight's safety with its pilot, and may delay, divert or cancel a flight if there is reason to do so. This checks and balances mechanism supposedly improves the safety of the dispatch system, although most countries do not use this system and there is no noticeable detriment to flight safety. A dispatcher typically must be licensed by the aviation authority of a country. The examination for the licence requires the candidate to

demonstrate knowledge in meteorology and aviation comparable to that required to obtain an Airline Transport Pilot Licence.

Mobile dispatch

In a mobile system, wireless technology is provided for efficient job planning, assignment and efficient job planning through the use of mobile dispatch systems sent out through a mobile network on to a mobile device such as PDA. This allows for more flexible management of the workers out in the field as a job can be dispatched to multiple users to accept or reject the job. The benefits of a mobile system as it can then be integrated back into the other software systems used by an organization such as asset management, rostering, and other financial systems.

Capacity and metrics

There is a limit to how many field units can be managed. This varies with circumstances. For example, a parcel delivery service dispatcher may encounter higher traffic around Christmas. Work is not evenly distributed across time: in any dispatch system there are traditional peaks or busy hours in requests for service. Some workplace cultures will allow longer wait times than others.

Systems may use a voice procedure to reduce talking time, allowing interaction with a larger dispatch fleet. Air traffic control and towing are two examples. The use of abbreviations or standard phrases can reduce the length of a transaction. Capacity may be reduced by relaxed voice procedure such as a delivery dispatcher giving a lengthy description of a customer complaint over the radio.

It's generally accepted that giving field units computers connected with the computer-aided dispatch, or another enterprise system used for dispatch, unloads voice two-way radio channels and increases capacity. Users research information on their terminal or laptop instead of calling in with a request that the dispatcher do it. One source suggests radio traffic drops by 30% when computers are available to mobile users.

Radio

Measurements of communications may reflect dispatch capacity. A partial definition of capacity comes from the number of communications channels required to support a dispatch fleet. Two metrics of channel capacity may be: 1) the number of field units or *resources* dispatched, and; 2)number of push-to-talk presses per day. A resource may refer to a fire engine, tow truck, taxi, or refuse truck, regardless of how many walkie-talkies, mobile radios, or persons were fielded along with each resource.

One suggestion is that 100 to 150 mobiles is the maximum practical on one channel. Another suggests 60-70 units as a maximum. The difference in these two ranges probably reflects the wording. For example, 120 *mobiles* may mean radios: 60 units each containing a mobile radio and an officer with a walkie talkie. For dispatch systems like

take-out food delivery, where life safety is not an issue, delays may be acceptable. Delays increase capacity.

Another possible measure of capacity is system push-to-talk presses. A 187-day study of four Contra Costa County, California Sheriffs Department conventional two-way radio dispatch channels showed an average of around 2,500 push-to-talk presses per day. The count was within +/-350 a day across all four primary dispatch channels.

Telephone

Multi-line phones are seen in many dispatching facilities. Rotary dials are rare.

A method used for telephone traffic analysis may fit some circumstances. One evaluation looked at 1) peak of busy hour usage, 2) average hourly usage, 3) message length in seconds, 4) maximum delay or wait time desirable, and; 5) maximum percent of users being delayed. Traffic analysis can be applied to radio or telephone communications.

Most office telephone systems have some facility for recording calling volumes, and incoming call timing. Dispatch centers use Automatic call distribution (ACD) groups which can be evaluated for metrics such as average wait time, abandoned calls, and calls per hour. These numeric data can be entered into spreadsheets for analysis of trends.

In dispatching, US emergency medical services literature suggests that telephone calls to a dispatching facility should be answered in the first few rings. One document suggests emergency calls to dispatch should result in busy signals once per 100 calls during the busiest hour. In business call centers, similar standards are suggested by consultants in order to provide an ideal customer experience and to outperform competing services. Sufficient staffing should be in place so that 90% of emergency calls are, "...answered within 10 seconds, or with no greater than three rings, during the average busy hour," according to one source. Tolerable wait times vary from one culture and region to another: some cultures expect immediate service; others will tolerate waits for some services.

Zone system to assign service calls

Dispatch consoles used by Denver RTD, a transit service provider in a US city. Drawing at right illustrates the controls associated with a single channel on the console.

One method for organizing assignments in a manual dispatch system is to use a zone map system. Consider a community with four fire stations and two ambulance service providers. A grid is overlaid on a community map. Saint Proximal Medical Center ambulance is identified by the notation *P* while Distal Volunteer Rescue Squad is noted with a *D*.

Each zone of the grid is identified with a progression of ambulance zones and fire stations. One zone might be labeled: DP241. This means fire station 2, then 4, then 1, then 3 would respond to a fire call occurring inside this zone. If fire stations 2, 4, and 1 were assigned to calls, Station 3 would be sent to this zone. Distal Volunteer Rescue Squad would be first-up for an ambulance call occurring inside zone DP241.

The predefined order is created by persons with expertise in the service being provided, local geography, traffic, and patterns in calls for service. In assigning resources to a zone, decision-makers may consider that responding units must drive around freeways, lakes, or terrain obstructions in order to reach a zone. Zone boundaries and designations will periodically change as communities grow or lessons are learned during day-to-day operations. Consider a zone with an irrigation canal defining one boundary. If a car crashes into the canal, which zone is it in?

Zone systems may include standby, move-up, or backfill points. For example, taxi drivers working in a certain zone in the evening hours may expect night club patrons to need a ride. Consider a standby point at Main Street and Railroad Avenue named *N*. Some fares will come from radio calls to dispatch. A taxi driver, Car 4, may go to predefined standby location *N*. In some dispatching systems, the driver will call the dispatcher and report they are available and located at standby point *N*. The dispatcher may respond by reporting the driver's position in the queue, "Car 4, second N." The first call in this district would go to the driver ahead of Car 4. Car 4 would be assigned the second call.

If automatic vehicle location is available, it would display service vehicle locations on a map. The closest unit would be interpreted by the dispatcher looking at vehicle locations projected on the map.

Chapter-14

Distribution Center

Sainsbury's distribution center in Waltham Point, Hertfordshire, United Kingdom.

A **distribution center** for a set of products is a warehouse or other specialized building, often with refrigeration or air conditioning, which is stocked with products (goods) to be redistributed to retailers, to wholesalers, or directly to consumers. A distribution center is a principal part, the order processing element, of the entire order fulfillment process. Distribution centers are usually thought of as being demand driven. A distribution center

can also be called a warehouse, a DC, a fulfillment center, a cross-dock facility, a bulk break center, and a package handling center. The name by which the distribution center is known is commonly based on the purpose of the operation. For example a "retail distribution center" normally distributes goods to retail stores, an "order fulfillment center" commonly distributes goods directly to consumers, and a cross-dock facility stores little or no product but distributes goods to other destinations.

Distribution centers are the foundation of a supply network, as they allow a single location to stock a vast number of products. Some organizations operate both retail distribution and direct-to-consumer out of a single facility, sharing space, equipment, labor resources, and inventory as applicable.

A typical retail distribution network operates with centers set up throughout a commercial market, with each center serving a number of stores. Large distribution centers for companies such as Wal-Mart serve 50–125 stores. Suppliers ship truckloads of products to the distribution center, which stores the product until needed by the retail location and ships the proper quantity.

Since a large retailer might sell tens of thousands of products from thousands of vendors, it would be impossibly inefficient to ship each product directly from each vendor to each store. Many retailers own and run their own distribution networks, while smaller retailers may outsource this function to dedicated logistics firms that coordinate the distribution of products for a number of companies. A distribution center can be co-located at a logistics center.

Scale

A large distribution center might receive and ship more than ten thousand truckloads each year, with an individual store receiving from only a couple trucks per week up to 20, 30, or more per week. Distribution centers range in size from less than 50,000 square feet (5,000 m^2) to the largest approaching 3 million square feet (300,000 m^2).

Storage

Although the primary role of a distribution center is to receive large quantities of products and ship small quantities to individual stores, an important secondary role is storage. Many retailers give priority to having as many items in stock at once as possible. To conserve space, minimize inventory costs, and maximize the variety they offer, the retailer might stock only one or a few items of a particular product. This requires the ability to ship a replacement quickly once an item is sold. By keeping product on hand in the distribution center, the retailer can ship a replacement almost immediately after a product is sold.

Storage locations and storage containers

Goods (products) arrive and are stored in a distribution center in varying types of storage locations and containers suited to the product characteristics and the amount of product to be transported or stored. These types of locations and containers have specific industry-accepted names. Specialized pieces of equipment (material handling equipment, or MHE) are used to handle the various types of containers. The following is a list of some of the names and characteristics of common storage containers:

- Intermodal containers (shipping containers) are used for the efficient transportation of goods. Standards that specify the volume and dimensions of containers to facilitate efficient handling.
- Pallets are one of the most commonly used means to store and move product in a distribution center. There are many specialized devices (MHE) used to handle pallets, pallet jack, pallet inverter, and unit load ASRS. Pallets are stored on the floor, may be stacked, and may be stored in pallet rack.
- Gaylords are large single boxes usually connected or attached to a pallet.
- Cases and Cartons are boxes usually containing many items. In distribution centers there is a generally accepted distinction made between the terms "carton" and "case", although both are boxes. Goods are received and stored in cartons, while goods are shipped in cases. A stored carton is called a case once it has been picked or pulled for shipment.
- Totes are reusable containers used to hold and transport goods.

Storage volume

In addition to shipping quickly, preparing for busy shopping seasons requires retailers to stock up on product ahead of time. For most retailers, the Christmas shopping season is the busiest of the year. Ahead of this time, a distribution center might double the amount of inventory on hand and then draw this level down through the shopping season. This strategy is especially important for imported items. With lead times measured in weeks or months, stocking these products in a distribution center is often the only way to maintain in-stocks at the store. New seasons, holidays, or special promotions may also prompt a retailer to store specific items prior to a large rollout or demand forecast.

Processing

Another way to look at a distribution center is to see it as a production or manufacturing operation. Goods arrive in bulk, they are stored until needed, retrieved, and assembled into shipments. The efficient processing of a distribution center can greatly impact the final price of the product delivered to the end user. Efficient processing not only directly impacts the cost of goods through reduced labor, but it also indirectly impacts the cost of goods through reduced inventory. Inventory represents an investment with its associated investment interest or inventory carrying cost. Reducing the processing time of order processing can directly reduce the amount of inventory necessary to be stocked in the operation.

Costs

The most efficient method of distribution would be to ship a full truckload or railcar directly from the manufacturer to the retailer. The next most efficient method would be to ship a full truckload to a distribution center, unload full pallets of products, and immediately load the pallets onto trucks destined for individual stores. Both of these methods can only be used on very high-volume items. Most products cannot be delivered in this manner, and pallets or even individual boxes must be broken down and divided.

Once a full pallet must be broken apart, the costs of handling the product can increase quickly. Many distribution centers use large sortation systems with miles of conveyor to move products through the facility and into a truck. They may also have automated equipment for de-palletizing and re-palletizing product. Some of the most sophisticated systems can convey product directly into storage racks and then convey out of the racks to trucks, all automatically. With a wide variety of product sizes and weights, these systems are designed to handle a specific range of products. Very large, small, heavy, or light products require varying degrees of manual handling.

As the process of handling involves more steps and becomes increasingly manualized, the cost increases. Storing products instead of receiving and immediately shipping them adds cost. Firms must determine when lost sales due to not having product on the shelves are balanced by increased handling and storage costs.

Distribution center organization

All distribution centers have three main areas and may have additional specialized areas. The three main areas are the receiving dock, the storage area, and the shipping dock. In small organizations it is possible for the receiving and shipping functions to occur side by side, but in large centers, separating these areas simplifies the process. Many distribution centers have dedicated dock doors for each store in their shipping area. The receiving area can also be specialized based on the handling characteristics of freight being received, on whether the product is going into storage or directly to a store, or by the type of vehicle delivering the product.

Distribution center planning

A number of components go into the overall planning of a distribution center in order to maximize its efficiency. If the distribution center relies on a conveyor system suspended from the ceiling, consideration needs to be given to the weight-bearing capacity of the ceiling joists. If the conveyor system runs along the floor, than consideration needs to be given in the design stage to the placement of columns, particularly as they relate to the flue space between pallet rack frames. Other planning considerations include attention to such areas as slotting, product replenishment, storage media, and power requirements.

Simple distribution center outline

Because many distribution centers service both large and small clients, especially those which store a specific type of service as opposed to those which serve a specific company, roles and departments are generally more complicated. A simple distribution center which serves many clients of a specific theme or type of service may include:

- Goods in: Usually containing specialized container unloading equipment and workers, including pallet wrapping, conveyor belt unloaders (as used on 40 ft shipping containers), forklift drivers, and administrative staff
- Bulk: As a rule, a bulk department controls and ships larger orders or orders that contain only full cartons/boxes. A bulk department includes forklift truck drivers to load containers and wagons, and *man-up* or *combi* forklift trucks to unload full pallets from warehouse racking.
- Break-bulk: Break-bulk (also known as split case) is a lower-capacity version of the *bulk* department. Orders usually contain part boxes or items not requiring pallets. Due to the number of smaller customers a distribution center may serve, a break-bulk department may need more workers than a bulk department. A break-bulk department usually uses trolleys or, for palleted/heavy orders, small electric *PPT* or *walkie low lift* trucks. Items shipped by break-bulk are usually stored in *pick,* which are usually the bottom two *pick-faces* of warehouse racking. A pick-face is the space on such a racking system onto which a pallet can be loaded.
- Export: An export department controls orders which are leaving the country of the distribution center. This department is almost identical in function to a bulk or break-bulk department; however, workers in this department build pallets conforming to different standards and sizes. An export department also uses different shipping containers or haulage firms.
- Quality assurance: A quality assurance (*QA*) department performs periodic checks of random samples of stock to check quality, including from the warehouse racking, goods in, and returned stock. This department may also take on cycle count duties to find missing stock.
- Administration
- Packing and production: In many distribution centers it is not feasible to store stock in many different packaging styles or quantities, and while it may cost a customer more to do so, many customers, such as supermarkets, prefer their own packaging on stock. Because of this, packing benches are used to take raw items, such as a box of balloons, and pack them at a specific unit quantity, which are then packed into cartons and labeled accordingly for a customer. In many circumstances this may be more inexpensively done at a distribution center than by a customer or client.
- Transportation: Arranges and coordinates shipments in and out of the distribution center.
- Dedicated product departments: Divisions may be based on handling characteristics or storage characteristics, for example, refrigerated and non-refrigerated [meat and produce, frozen, dairy/deli, dry]. Each of these three areas have both shipping and receiving departments as well.

Distribution centers also have a variety of supporting departments, including human resources, maintenance/facilities operations, production control, and accounting.

Distribution jobs

A distribution center typically has a general manager who manages the facility and typically has a number of department managers who report directly to him/her. Most distribution centers divide staff into two categories, direct labor and indirect labor. Direct labor staff execute the distribution processes, while indirect labor staff support the direct labor staff. Each department is in turn composed of supervisors and warehouse workers. The direct labor jobs of a warehouse can include:

- Unloader - unloads trucks and breaks down pallets as needed, using various pieces of power equipment
- Receiver - inventories and tags unloaded pallets using a mobile cart computer unit and printer
- Hauler - transports received pallets with equipment from the receiving dock to the storage racks
- Putaway driver - puts product into racks with forklift
- Lumper - helps unload shipments
- Replenishment driver - pulls product from the racks and places it into the "pick slot" with forklift
- Order filler - picks product from the "pick slot" by hand and moves with power equipment
- Loader - wraps the order-filled pallets and loads trucks, using equipment

Indirect labor departments and jobs within a warehouse can include:

- Supervision - floor (process) supervision, indirect labor supervision
- Human resources - employment office and employee benefits
- Facilities and housekeeping - maintenance of buildings
- Inventory management - tracking and placement of product
- Quality assurance - inspection and acceptance of incoming and outbound product
- Asset protection - building security and loss prevention
- Safety - insurance of safe operating practices
- Equipment maintenance - electrical, mechanical, and pneumatic maintenance of MHE
- Operations research - Industrial engineering, process improvement, labor standards
- Information technology - support of information systems

Chapter-15

Freight Audit and Insulated Shipping Container

Freight audit

Definition

By definition an **audit** is,

- An examination of records or financial accounts to check their accuracy.
- An adjustment or correction of accounts.
- An examined and verified account.

A **freight audit vendor** is therefore one who examines, adjusts and verifies freight bills for accuracy.

Therefore, a freight audit is the process of examining, adjusting and verifying freight bills for accuracy.

Freight costs

- Costs incurred by the merchant in moving goods, by whatever means, from one place to another under the terms of the contract of carriage. In addition to transport costs this may include such elements as packing, documentation, loading, unloading and transport insurance.

Complexity of Freight Audit

Rising freight cost is an emerging area of concern as seen in recent years. The cost of freight has been rising due to the increase in oil prices and all freight cost is highly dependent on the cost of transportation which relates directly to fuel prices. With high fluctuations of fuel costs, low visibility of the future freight costs and high complexity of the freight quotes, freight cost verification are vulnerable to human and process errors

and this requires proper auditing to ensure that the organization does not overpay for services it did not incur.

The forwarder freight rates are usually maintained in multiple spreadsheets and usually each forwarder has a different freight rate format to the customer. An organization is daunted with the task of calculating the freight rates manually and this task can be challenging when the customer has hundreds of shipments shipped each month. Most organizations do not have the manpower to calculate all the freight invoices issued to them and at best, they perform random sampling to check if the sample invoice is billed correctly. Some organizations have the manpower to perform freight audit themselves, the manual and tedious efforts required for a freight audit will usually end up much more expensive than an outsource vendor might be able to provide.

Based on the research of inboundlogistics.com, freight costs can make up 10% of an organization's expenditure . As a consequence of rising freight costs, an increasing number of organizations has been more proactive in controlling freight cost and outsourced the freight audit process to freight audit specialists.

Freight Audit Process

Inbound logistics details the freight audit process as "To begin the auditing process, a freight bill payment company receives its clients' freight bills directly from carriers. When the bills are received, either via electronic data interchange (EDI) or manually, they are entered into the contractor's system, providing immediate visibility. Once the bills are entered, they are audited for accuracy. Auditors verify the bills' validity, mileage, duplicate payments, accessorial charges, and use of correct tariffs. After auditing, the charges are coded and reconciled, and the bills are paid."

Some companies have gone forward with a process to pay freight bills called self billing. The customers calculate their freight cost themselves and instruct the freight forwarder to invoice using credit notes. This process transfers the responsibility to correct freight calculation from the customer to the forwarder.

Models of freight audit

GT Nexus noted that there are 3 models of freight audit in used today. The 3 models are listed as below.

1. Manual match—Pay for in-house staff to manually process invoices and conduct audits, with costs, errors and unrecovered charges rising as international transportation volumes grow;
2. Buy packaged software—Pay an upfront license to acquire a software package, and then install, operate and maintain the software, rates, and electronic integrations to carriers, using expensive internal resources; or

3. Outsource -- Pay fees to a third-party firm, send them freight invoices, and then absorb additional costs and time to administer the service, track discrepancies, and recoup unrecovered charges.

The first option of manual matching is tedious and the cost of auditing a freight invoice rise with the number of freight invoice proportionally.

The 2nd option of buying packaged software allows the company to save time and resources in the invoice processing but the company will need to invest in the training of the staff and system infrastructure to maintain an expert process and system. The freight audit system will be able to eliminate the mundane freight calculation and matching process and the users of the system will be able to perform value add activities such as analyzing freight rates, negotiation with freight forwarders or recovering freight invoice discrepancy with freight forwarders.

For option 3, ideally, the 3rd party firm should use a freight audit system and not handle the freight invoices manually. The freight audit system maintained by a team of expert users will eliminate the cost of training users and infrastructure setup cost. Although the cost of outsource may seem to be higher than buying a packaged software, it includes the maintenance cost of a freight system which may cost more for a team of non experts from the customer to manage.

Insource audit names model 2 and model 3 ASP, application service provider, and BPO, business process outsourcing respectively . These business models converges expert systems with organisation capability and trained staffs, the combined knowledge of the organisation and the vendor has the benefit of the combination of knowledge and resources. Hence these 2 models are well positioned to take on the challenges of tomorrow's freight audit.

Freight audit on shipment or freight invoice level

Freight audit can be conducted at the shipment or freight invoice level. A company that has standard weights for standard packages may opt to audit freight invoices at freight invoice level to reduce complexity in the freight audit process. This is known as freight invoice validation and this process is simple as compared to a freight audit at shipment level. A company that has a more complex shipping process may choose to go for freight invoice verification. This freight invoice verification process is a flexible solution that allows the customer to use their shipment and package measurements and calculate against the freight quotes and finally compared against the freight invoice. By having detail shipment information, customers can analyze freight cost by product line reports or interface payment information into their ERP systems.

Benefits of freight audit

Inbound logistics noted that for many companies, outsourcing could be the most economical way to properly audit and process freight invoices. They have also noted that

the cost to verify, process and finally pay an internal freight invoice is around USD 11 and the cost of outsourcing is around 5 to 10% of the internal cost and that has not included the cost savings from the invoice discrepancies. The discrepancies can be as much as 8.8% of the freight invoices. CT Logistics believes that accuracy of a freight invoice is assured by outsourcing because freight audit company audits for freight rates, freight discounts, misapplied accessorial charges, and prevent possible duplication of payment. The provider of a freight audit can also provide comprehensive reports for the customer to make intelligent business decisions such as consolidation of shipments to a certain forwarder and landed costing of each product group. These reports are critical to a product costing and planning strategy in order to make the product successful in the targeted area.

Freight cost reports can be generated to compare the freight costs for forwarders and the customers may use such reports to flag out service failures, negotiate for better freight deals or the opportunity to consolidate the shipments to a forwarder for a better rate. Customers can simulate the freight cost calculation for new freight rates or packages proposed by the forwarder and determine if this is suitable for their business model . With large fluctuations in the surcharges, the accounts department will have lower visibility in accruing freight cost. By choosing a freight invoice verification model, a customer can forecast the freight cost to be accrued for accounting purposes. This translates to lesser risk and more predictability in cash flow for the company . Akzo Nobel's automated freight audit process has also instilled tighter controls over their freight accounting by eliminating human communication and intervention from the point of the freight quote to the payment process. By controlling the human communication and minimizing human intervention, the audit process will be unbiased and less likely to deviate from the proper process.

Insulated shipping container

Insulated shipping containers are a type of packaging used to ship temperature sensitive products such as foods, pharmaceuticals, and chemicals. They are used as part of a cold chain to help maintain product freshness and efficacy. The term can also refer to insulated intermodal containers or insulated swap bodies.

Construction

An insulated shipping container might be constructed of:

1. a vacuum flask, similar to a "thermos" bottle
2. fabricated thermal blankets or liners
3. molded expanded polystyrene foam (EPS, styrofoam, etc), similar to a cooler
4. other molded foams such as polyurethane, polyethylene, etc
5. sheets of foamed plastics
6. reflective materials: (metallised film, etc)
7. bubble wrap or other gas filled panels
8. other packaging materials and structures

Some are designed for single use while others are returnable for reuse. Some empty containers are sent to the shipper disassembled or “knocked down”, assembled and used, then knocked down again for easier return shipment.

Use

Insulated shipping containers are part of a comprehensive cold chain which controls and documents the temperature of a product through its entire distribution cycle. The containers may be used with a refrigerant or coolant such as :

- block or cube ice, slurry ice, etc
- dry ice
- Gel or ice packs (often formulated for specific temperature ranges)
- Some products (such as frozen meat) have sufficient thermal mass to contribute to the temperature control
- etc

A temperature data logger or time temperature indicator is often enclosed to monitor the temperature inside the container for its entire shipment.

Labels and appropriate documentation (internal and external) are usually required.

Personnel throughout the cold chain need to be aware of the special handling and documentation required for some controlled shipments. With some regulated products, complete documentation is required.

Design and Evaluation

The use of “off the shelf” insulated shipping containers does not necessarily guarantee proper performance. Several factors need to be considered :

- the sensitivity of the product to temperatures (high and low) and to time at temperatures
- the specific distribution system being used: the expected (and worst case) time and temperatures
- regulatory requirements
- the specific combination of packaging components and materials being used
- etc

In specifying an insulated shipping container, the two primary characteristics of the material will be the insulation properties of the matieral known as the "K Value" and the thickness of the material. These two attributies determine that majority of the functionality of the component. One should attempt to control the latent heat of any insultated shipping container when is use, as this will affect the overall performance of the component when integrated into a system (closed system with refrigerant & product).

It is wise (and sometimes mandatory) to have formal verification of the performance of the insulated shipping container. Laboratory package testing might include ASTM D3103-07, Standard Test Method for Thermal Insulation Performance of Packages, ISTA Guide 5B: Focused Simulation Guide for Thermal Performance Testing of Temperature Controlled Transport Packaging, and others. In addition, validation of field performance is extremely useful.

Specialists in design and testing of packaging for temperature sensitive products are often needed. These may be consultants, independent laboratories, universities, or reputable vendors.

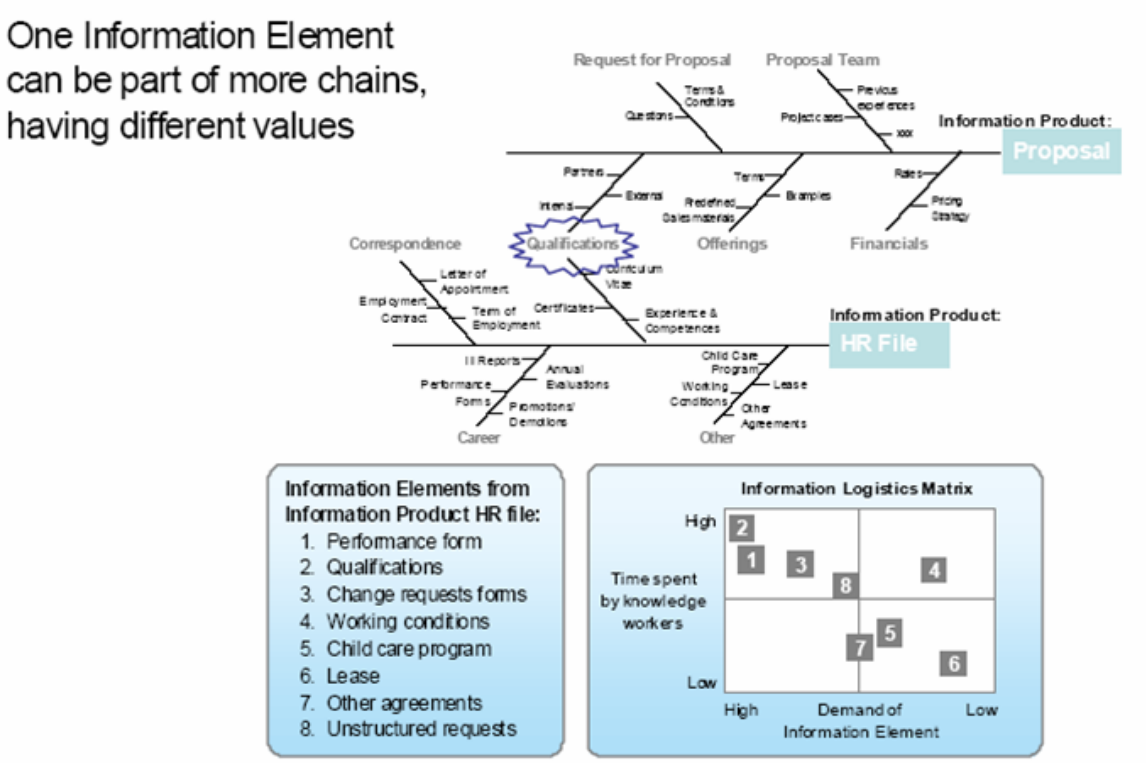
Chapter-16

Information Element and Information Logistics

Information Element

1. In terms of information logistics (IL), an **Information Element** (IE) is an information component that is located in the organizational value chain. The combination of certain IEs leads to an information product (IP), which is any final product in the form of information that a person needs to have. When a higher number of different IEs are required, it often results in more planning problems in capacity and inherently leads to a non-delivery of the IP.

To illustrate the concept of an IP, an example is shown of a bottleneck analysis in HR (by J. Willems 2008). Here, the illustration shows how the Information Elements (e.g. Qualifications) build up the Information Product (e.g. HR File).



2. In terms of ICT, an **Information Element** (IE) is a part of management frames in the IEEE 802.11 wireless LAN protocol. IEs are a device's way to transfer descriptive information about itself inside management frames. There are usually several IEs inside each such frame, and each is built of TLVs mostly defined outside the basic 802.11 specification.

The common structure of an IE is as follows:

```
 ← 1 →  ← 1 →   ←       3       →   ←  1-252  →
-----------------------------------------------
|Type  |Length|        OUI         |     Data    |
-----------------------------------------------
```

Whereas the OUI (Organizationally Unique Identifier) is only used when necessary to the protocol being used, and the Data field holds the TLVs relevant to that IE.

Information logistics

Information logistics (IL), as a section of information management, deals with the flow of information within an organizational unit or between any number of organizations that in turn form a value creating network.

Definition

- Information Logistics (IL) can be defined as "managing and controlling information handling processes optimally with respect to time (flow time and capacity), storage, distribution and presentation in such a way that it contributes to company results in concurrence with the costs of capturing (creation, searching, maintenance etc)."

Goal

- The goal of Information Logistics is to deliver the right information product, consisting of the right Information Element, in the right format, at the right place at the right time for the right people and all this customer demand driven.
- If this goal is achieved, the knowledge worker is best equipped with information for the task at hand for improved interaction with its customers.

With other words, information logistics is about providing:

- the correct information product
- at the accurate point of time
- in the correct format / quality
- for the intended recipient
- at the right location

Methods for achieving the goal are:

- the analysis of the information demand
- intelligent information storage
- the optimization of the flow of information
- securing technical and organizational flexibility

The expression was formed by the Indian mathematician and librarian S. R. Ranganathan.

The supply of a product is part of the discipline Logistics. The purpose of this discipline is described as follows:

Logistics is the teachings of the plans and the effective and efficient run of supply. The contemporary logistics focuses on the organization, planning, control and implementation

of the flow of goods, money, information and flow of people.

Information Logistics focusses on information. Information (from Latin informare: "shape, shapes, instruct") means in a general sense everything that adds knowledge and thus reduce ignorance or lack of precision. In stricter sense information becomes information only to those who can interpreted it. Interpreting information will provide knowledge.

These definitions explain what the Information Logistics is all about. The provision of information for the knowledge worker within the correct context, enabling him or her to make the right decision.

Chapter-17

Inventory Management Software

Inventory management software is a computer-based system for tracking product levels, orders, sales and deliveries. It can also be used in the manufacturing industry to create a work order, bill of materials and other production-related documents. Companies use **inventory management software** to avoid product overstock and outages. It is a tool for organizing inventory data that before was generally stored in hard-copy form or in Microsoft Excel spreadsheets.

Components

Inventory management software is made up of several components, all working together to create a cohesive inventory control system. These components include (in alphabetical order):

Asset tracking

When a product is in a warehouse or store, it can be tracked via its bar code and/or other tracking criteria, such as serial number, lot number or revision number.

Barcoding

Barcodes are the means whereby data on products and orders is inputted into inventory management software. A barcode reader is required to read barcodes and look up information on the products they represent.

Order management

Once products reach a certain low level, a company's inventory management system can be programmed to tell managers to reorder that product. This helps companies avoid running out of products or tying up too much capital in inventory.

Service management

Companies that are primarily service-oriented rather than product-oriented can use inventory management software to track the cost of the materials they use to provide services, such as cleaning supplies. This way, they can attach prices to their services that reflect the total cost of performing them.

History

The Universal Product Code (UPC) was adopted by the grocery industry in April 1973 as the standard barcode for all grocers, though it was not introduced at retailing locations until 1974. This helped drive down costs for inventory management because retailers in the United States and Canada didn't have to purchase multiple barcode readers to scan competing barcodes. There was now one primary barcode for grocers and other retailers to buy one type of reader for.

In the early 1980s, personal computers (PCs) debuted and started becoming popular. This further pushed down the cost of barcodes and readers. It also allowed the first versions of inventory management software to be put into place. One of the biggest hurdles in selling readers and barcodes to retailers was the fact that they didn't have a place to store the information they scanned. As computers became more common and affordable, this hurdle was overcome. Once barcodes and inventory management programs started spreading through grocery stores, inventory management by hand became less practical. Writing inventory data by hand on paper was replaced by scanning products and inputting information into a computer by hand.

Starting in the early 2000s, inventory management software progressed to the point where businesspeople no longer needed to input data by hand but could instantly update their database with barcode readers.

Purpose

Companies often use inventory management software to reduce their carrying costs. The software is used to track products and parts as they are transported from a vendor to a warehouse, between warehouses, and finally to a retail location or directly to a customer.

Inventory management software is used for a variety of purposes, including:

- Maintaining a balance between too much and too little inventory.
- Tracking inventory as it is transported between locations.
- Receiving items into a warehouse or other location.
- Picking, packing and shipping items from a warehouse.
- Keeping track of product sales and inventory levels.
- Cutting down on product obsolescence and spoilage.

Manufacturing uses/applications

Manufacturers mainly use inventory management software to create work orders and bills of materials. This facilitates the manufacturing process by helping manufacturers efficiently assemble the tools and parts they need to perform specific tasks. For more-complex manufacturing jobs, manufacturers can create multilevel work orders and bills of materials, which have a timeline of processes that need to happen in the proper order to build a final product. Other work orders that can be created using inventory management software include reverse work orders and auto work orders. Manufacturers also use inventory management software for tracking assets, receiving new inventory and additional tasks businesses in other industries use it for.

Advantages

There are several advantages to using inventory management software in a business setting.

Cost savings

In many cases, a company's inventory represents one of its largest investments, along with its workforce and locations. Inventory management software helps companies cut expenses by minimizing the amount of unnecessary parts and products in storage. It also helps companies keep lost sales to a minimum by having enough stock on hand to meet demand.

Warehouse organization

Inventory management software can help distributors, wholesalers, manufacturers and retailers optimize their warehouses. If certain products are often sold together or are more popular than others, those products can be grouped together or placed near the delivery area to speed up the process of picking, packing and shipping to customers.

Updated data

Up-to-date data on inventory conditions and levels is also an advantage inventory management software gives companies. Company executives can usually access the software through a mobile device, laptop or PC to check current inventory numbers.

Time savings

With the aid of restricted user rights, company managers can allow many employees to assist in inventory management. They can grant employees enough information access to receive products, make orders, transfer products and do other tasks without compromising company security. This can speed up the inventory-management process and save managers' time.

Disadvantages

The main disadvantages of inventory management software are its cost and complexity.

Expense

Cost can be a major disadvantage of inventory management software. Many large companies, such as Polo Ralph Lauren, Macy's, Nordstrom and Wal-Mart, use inventory management software, but small businesses can find it difficult to afford it. Barcode readers and other hardware can compound this problem by adding even more cost to companies. The advantage of allowing multiple employees to perform inventory-management tasks is tempered by the cost of additional barcode readers.

Complexity

Inventory management software is not necessarily simple or easy to learn. A company's management team must dedicate a certain amount of time to learning a new system, including its software and hardware, in order to put it to use. Most inventory management software includes training manuals and other information available to users. Despite its apparent complexity, inventory management software offers a degree of stability to companies. For example, if an IT employee in charge of the system leaves the company, a replacement can be comparatively inexpensive to train compared to if the company used multiple programs to store inventory data.

Chapter-18

DASH7

DASH7 is a new wireless sensor networking technology using the ISO/IEC 18000-7 standard for active RFID, operating at in the 433 MHz unlicensed spectrum. DASH7 provides multi-year battery life, range of up to 2 km (potentially farther), low latency for tracking moving objects, small protocol stack, sensor and security support, and data transfer of up to 200 kbit/s. DASH7 is the name of the technology promoted by the non-profit consortium called the DASH7 Alliance.

International Standard

DASH7 follows the ISO/IEC 18000-7 open standard for the license-free 433 MHz ISM band air interface for wireless communications. 433 MHz is available for use worldwide. The wireless networking technology was originally created for military use and is now being re-purposed for many commercial applications in place of wireless protocols like ZigBee or IEEE 802.15.4.

History

In January 2009, the U.S. Department of Defense announced the largest RFID award in history, a $429 million contract for DASH7 devices, to three hardware vendors: Savi Technology, Evigia Systems, and Identec Solutions.

In March 2009, the DASH7 Alliance, a non-profit industry consortium to promote interoperability among DASH7-compliant devices, was announced and as of July 2010 has more than 50 participants in 23 countries. Similar to what the WiFi Alliance does for IEEE 802.11, the DASH7 Alliance is doing for the ISO 18000-7 standard for wireless sensor networking.

Technical summary

DASH7 contrasts with existing wireless data technologies like ZigBee:

Technology	Global standard used	Frequencies used	Globally available frequency (ies)?	Penetrates water	Penetrates concrete	Range	Average power draw	Average latency	Device cost	Multi-hop capabilities	Sensor and Security support	Interference from 802.11n	Maximum bit rate
DASH7	ISO/IEC 18000-7	433.92 MHz	Yes	Yes	Yes	1,000 m	30–60 µW	2 seconds worst case	$10+	Yes	Yes	No	200 kbit/s
ZigBee	IEEE 802.15.4	2.4 GHz, 915 MHz, 868 MHz	2.4 GHz – yes; 915 MHz – no; 868 MHz – no	No	No	30–500 m	125–400 µW	varies from seconds to potentially minutes	$10+	Yes	Yes	Yes	250 kbit/s

433.92 MHz

DASH7 utilizes the 433.92 MHz frequency, which is globally available and license-free. 433.92 MHz is ideal for wireless sensor networking applications since it penetrates concrete and water, but also has the ability to transmit/receive over very long ranges without requiring a large power draw on a battery. The low input current of typical tag configurations allows for battery powering on coin cell or thin film batteries for up to 10 years.

Tag-to-Tag Communications

Unlike most active RFID technologies, DASH7 supports tag-to-tag communications which, combined with the long range and signal propagation benefits of 433 MHz, makes it an easy substitute for most wireless "mesh" sensor networking technologies. DASH7 also supports sensors, encryption, IPv6, and other features.

BLAST networking technology

Networks based on DASH7 differ from typical wire-line and wireless networks that operate with a "session". DASH7 networks serves applications in which low power usage is essential, and data transmission is typically much slower and/or sporadic, like basic telemetry. So instead of replicating a wire-line "session", DASH7 was designed with the concept of BLAST:

*B*ursty
: Data transfer is abrupt and does not include content such as video, audio, or other isochronous forms of data.

*L*ight
: For most applications, packet sizes are limited to 256 bytes. Transmission of multiple, consecutive packets may occur but is generally avoided if possible.

*AS*ynchronous
: DASH7's main method of communication is by command-response, which by design requires no periodic network "hand-shaking" or synchronization between devices.

*T*ransitive
: A DASH7 system of devices is inherently mobile or transitional. Unlike other wireless technologies DASH7 is upload-centric, not download-centric, so devices do not have to be managed extensively by fixed infrastructure (i.e. base stations).

Range

DASH7 devices today advertise read ranges of 1 kilometre or more, however ranges of up to 10 km have been tested by Savi Technology and are easily achievable in the European Union where governmental regulations are less constrained than in the USA.

Interoperability

DASH7 devices use a single global frequency, which simplifies deployment and maintenance decisions relative to specifications using multiple frequencies. A neutral, third party testing authority also conducts conformance and interoperability testing under the DASH7 Certified program.

Commercial Applications

Similar to other networking technologies that began with defense sector (e.g. DARPA funding the Internet), DASH7 is similarly suited to a wide range of applications in development or being deployed including:

- **Mobile Advertising** DASH7 is being developed for "smart" billboards and kiosks, as well as "smart" posters that can be ready from many meters (or even kilometers) away, creating new opportunities for both tracking the effectiveness of advertising spend but also creating new e-commerce opportunities. DASH7's potential to automate check-ins and check-outs provides essential infrastructure to location-based advertising and promotions

- **Location-Based Services** DASH7 is being used today to develop new location-based services using a range of DASH7-enabled devices including smartcards, keyfobs, tickets, watches and other conventional products that can take advantage of the unique small footprint, low power, long range, and low cost of DASH7 relative to less practical and high-power wireless technologies like WiFi or Bluetooth. Using DASH7, users can "check in" to venues in ways not practical with current check-in technologies like GPS, that are power-intensive and fail indoors and in urban environments. Location-based services like Foursquare, Novitaz, or Facebook can exploit this capability in DASH7 and award loyalty points, allow users to view the Facebook or Twitter addresses of those walking past, and more.

- **Ticketing** DASH7 can replace paper-based systems with low cost wireless systems that can be deployed using flexible substrates and thin-film batteries.

- **Building Automation, Access Control, Smart Energy** . DASH7's signal propagation characteristics allow it to penetrate walls, windows, doors, and other substances that serve as impediments to other technologies operating at 2.45 GHz, for example. For smart energy and building automation applications, DASH7 networks can be deployed with far less infrastructure than competing technologies and at far lower total cost of ownership.

- **Automotive** DASH7 is increasingly seen as the next-generation tire pressure monitoring system given its operation at the same frequency (433 MHz) as nearly all proprietary TPMS systems today. DASH7-based TPMS will provide end users with more accurate tire pressure readings, resulting in greater fuel economy, reduced tire wear and tear, and greater safety. DASH7 products are also being designed and used for other automotive applications like supply chain visibility.

- **Logistics** DASH7 is being used today to track the whereabouts of shipping containers, pallets, roll cages, trucks, rail cars, maritime vessels, and other supply chain assets, providing businesses with unprecedented visibility into their everyday operations. Also: cold chain management (vaccines, fresh produce, cut flowers, etc.), whereby DASH7 is used to monitor the in-transit temperature and other environmental factors that can impact the integrity of sensitive products.

As NATO militaries continue to deploy DASH7 infrastructure, defense suppliers are expected to also deploy DASH7 infrastructure given NATO requirements for supply chain visibility beyond just physical boundaries of a given military and deep into the supply chains of an array of suppliers around the world. DASH7 is expected to be adopted similar to the way barcoding was rapidly adopted by commercial companies, many of whom are also defense suppliers, following the LOGMARS barcoding mandate from the U.S. Department of Defense in 1981.

Defense Applications

DASH7 is being used extensively by the U. S. Department of Defense (DoD) and other militaries. In January 2009, DoD awarded a $429 million contract for DASH7 devices, making it one of the largest wireless sensor networking deployments in the world, especially when combined with DoD's $500 million + installed base of non-DASH7 infrastructure which DoD is upgrading to DASH7.

Commenting on the U.S. Department of Defense's move to an RFID III multi-vendor contract earlier this year, Lt. Col. Pat Burden, the DoD's Product Manager Joint-Automatic Identification Technology, stated, "This is a significant milestone for DoD in that this migration will not only give DoD and other Federal agencies' customers best-value solutions at competitive prices, but it moves us to ISO 18000-7:2008 compliant products, thus broadening interoperability with DoD and our coalition partners."

NATO military forces are required to interoperate with DoD's DASH7 network and are required to deploy interoperable infrastructure. All NATO militaries are deploying or in the process of deploying DASH7 infrastructure.

Semiconductor Industry Support

DASH7 developers receive support from the semiconductor industry including multiple options, with Texas Instruments, ST Microelectronics, Melexis, Semtech and Analog Devices all offering DASH7 hardware development kits or system-on-a-chip products. Texas Instruments also joined the DASH7 Alliance in March 2009 and announced their CC430 system-on-a-chip product for DASH7 in December 2009. Analog Devices also announced their ADuCRF101 single chip solution for DASH7 in November 2010.

One semiconductor industry approach is the combination of DASH7 with MEMS sensing products:

"We strongly believe that the next big wave in sensors will be driven by the combination of the sensing function with wireless transmission – and ISO 18000-7 is the right solution for security and asset monitoring applications," said Benedetto Vigna, group vice president and general manager of the MEMS and Healthcare Product Division at STMicroelectronics in the company's announcement. "The Smart Web-Based Sensor HDK is a best-in-class development platform that will help the adoption of wireless sensors across the industry."

ST Microelectronics announced the beta version of its DASH7 SmartSensor developers kit in May 2009 in collaboration with Arira Design.

Another semiconductor industry approach focuses on automotive:

"There is a great potential for DASH7 technology in the automotive area," said Gilles Cerede, Product Line Manager for Wireless Automotive & Sensing at Melexis. "We see a perfect fit between DASH7 features and performance and the requirements of wireless safety applications. For example the ultra low power consumption matches the TPMS life time constraints, while the "multi-kilometer" communication range is perfectly suited for car-to-car and car-to-infrastructure applications. Last but not least, DASH7 is compatible from a frequency point of view with existing Remote Keyless Entry systems."

DASH7 is also seen as a complement to 13.56 MHz NFC (Near Field Communications), where both technologies can "co-exist" in the same silicon with only minor adjustments to the NFC silicon to accommodate DASH7.

Device Integrators

Many companies are members of the DASH7 Alliance to produce DASH7-compliant hardware products, including:

- Confidex
- Convergence Systems
- DH Technology
- Evigia Systems
- Guard RFID
- Identec Solutions
- Cubic Global Tracking Solutions
- Lyngsoe Systems
- Novitaz
- RFind Systems
- Savi Technology (Lockheed Martin)
- Syrma
- Systems Planning Corp
- UDEA

The ISO/IEC 18000-7 Air Interface Standard

The original ISO 18000-7 standard was ratified in 2004 then modified in 2008. According to ISO:

ISO/IEC 18000-7:2009 defines the air interface for radio frequency identification (RFID) devices operating as an active RF tag in the 433 MHz band used in item management applications. It provides a common technical specification for RFID devices that can be used by ISO technical committees developing RFID application standards. ISO/IEC 18000-7:2009 is intended to allow for compatibility and to encourage inter-operability of products for the growing RFID market in the international marketplace. ISO/IEC 18000-7:2009 defines the forward and return link parameters for technical attributes including, but not limited to, operating frequency, operating channel accuracy, occupied channel bandwidth, maximum power, spurious emissions, modulation, duty cycle, data coding, bit rate, bit rate accuracy, bit transmission order, and, where appropriate, operating channels, frequency hop rate, hop sequence, spreading sequence, and chip rate. ISO/IEC 18000-7:2009 further defines the communications protocol used in the air interface.