# Driving Excellence in Quality Management through Information Systems

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**Abstract**— Powerful systems for collecting data and managing it in large databases are already in place in most large and medium-scale companies. However, the bottleneck of turning this data into success is the difficulty of extracting knowledge about the system from the collected data to generate a profitable product that caters to the needs of the customer. With technology changing at a breakneck pace, it is essential for organizations to work towards an intelligent system that not only strives towards maintaining the quality of a product but also keeps room for up gradation. With more people being aware of the importance of quality, manufacturing organizations continuously face the challenge of effectively managing the quality of their products while optimizing the production process. This project gives an overview of a four layer structure, merging the manufacturing process with Information Technology tools that eventually creates a flexible system integrating all business activities. This project also introduces the key concepts of Enterprise Resource Planning, Data Warehouse and Data Mining, which forms the backbone of the system.

**Index Terms**— Data Mining, Data Warehousing, Distributed Control System (DCS), Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), Programmable Logic Controllers (PLC), Quality, Supervisory Control and Data Acquisition (SCADA).

## 1 INTRODUCTION

COMPANIES are facing increased pressures in the form of global competition, demand-driven supply chains, and from the challenge to remain cost-competitive by generating a wider product offering having a greater variety of product specifications and performance features. These issues have forced many to consider how they can integrate a variety of manufacturing and control processes using a singular approach.

The focus is always on the quality of the product. Quality determines a company's profitability and productivity. Since it directly affects costs, companies must be aware of the quality management process. While using less expensive equipments and obsolete technology might cut down short term costs, the long term effects may turn out to be much more expensive and hinder customer satisfaction. Hence, it is necessary to devise a system that can manage all aspects of an organization

Information Systems make this task easier by consolidating all individual functionalities of an organization. An Information System (IS) is any combination of Information Technology (IT) and people's activities using that technology to support operations, management, and decision-making. In a very broad sense, the term information system is frequently used to refer to the interaction between people, algorithmic processes, data and technology.

The following are the categories of information systems in manufacturing:

- *Operational Improvement* – the operational information systems provide the tools needed to run the business on a day–by–day basis. They provide real time information about costs, productivity, and operational efficiency. They include information, work planning and operational control for:
  - Materials management
  - Flexible manufacturing
  - Machine tool control
  - Automated process control
- *Advanced Manufacturing Technologies* – the control of machinery through automated work instructions, machine tool instructions, and other non–human intervention processes that contribute directly to the bottom line of the business.
- *Information Systems* – the application software that forms the basis of the operational efficiency and advanced machine control, is dependent on the order entry, production scheduling and shop floor control facilities provided by:
  - *ERP* – enterprise resource planning. It is an accounting oriented information system for identifying and planning enterprise wide resources needed to take, make, ship, and account for customer orders.
  - *PDM* – product data management. It is a collection of applications that maintain the logical and physical relationships between the various components of a product.
  - *Product Configuration* – provides the management of the configuration processes. A Configurator provides knowledge based rules and constraints for assembling parts into products or systems to be delivered against a customer order.
  - *EDM* – enterprise document management. It is an infrastructure system, which document–enables business process and application through workflow and a document repository. The primary function of EDM is to manage the change to business critical documents and delivery these document to the proper user at the proper time.

With ERP playing the central control system by which sub-

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sequent systems can exchange information, all activities of the organization work in sync. It provides an integrated environment that allows management to align business functions and organize data for maximum business intelligence. ERP systems can optimize business transactions, reduce the total cost of information systems, create common business processes, and add value to customers. This streamlines workflows and establishes uniform processes that are based on recognized best business practices. ERP along with Data Mining tools transforms any system to an intelligent system. Data mining and analysis tools are excellent resources to evaluate data taken from internal audits and identify risks and recommend ways to mitigate them. This flexible software can directly query the databases within ERP applications to extract data and import it into data analysis tools for further investigation.

Thus, the aim of this project is to present a system that can monitor and manage product quality as well as optimize the production process by integrating and implementing Information Technology tools in different levels of the organization.

## 2 SIGNIFICANCE OF QUALITY IN AN ORGANIZATION

### 2.1 What does Quality mean?

Quality has been an elusive concept in business. Many people think of quality as some level of superiority or innate excellence; others view it as a lack of manufacturing defects. The official definition of quality, standardized by the American National Standards Institute (ANSI) and the American Society for Quality Control (ASQC) in 1978, is

"The totality of features and characteristics of a product or service that bears on its ability to satisfy given needs."[1]

This definition implies that we must be able to identify the features and characteristics of products and services that determine customer satisfaction and form the basis for measurement and control. The "ability to satisfy given needs" reflects the value of the product or service to the customer, including the economic value, safety, reliability, and maintainability.

Quality can be defined in two ways:

*Fitness of purpose*: Although the ANSI/ASQC definition of quality is operationally useful, it does not completely describe the various viewpoints of quality that are commonly used: Since customer needs must be the driving force behind quality products and services, a popular definition of quality is fitness for use. This is encompassed in the ANSI/ASQC definition as "the ability to satisfy given needs." This definition means that a quality product or service must meet customer requirements and expectations.

*Conformance to specification*: A second approach to defining quality, from the perspective of manufacturing or service delivery, is conformance to specifications. Specifications are targets and tolerances determined by designers of products and services: Targets are the ideal values for which production is expected to strive; tolerances are acceptable deviations from these ideal values, recognizing that it is impossible to meet the targets all the time.

### 2.2 Quality in Manufacturing Systems

In manufacturing, quality is an important component of all functions. For example, effective market research is necessary to determine customer needs and identify functional requirements for product designers. Product designers must take care to neither over-engineer (resulting in inefficient use of a firm's resources) nor under-engineer products (resulting in poor quality). Purchasing must ensure that suppliers meet quality requirements. Also, Production planning and scheduling cannot put undue pressure on manufacturing that will degrade quality. Tool engineering and maintenance are responsible for ensuring that tools, gadgets, and equipment are properly maintained. Industrial engineering selects the appropriate technology that is capable of meeting design requirements and developing appropriate work methods. Packaging, shipping, and warehousing have the responsibility of ensuring the condition, availability, and timely delivery of products in transit. Ancillary functions such as finance, human resources, and legal services support the quality effort by providing realistic budgets, a well-trained and motivated workforce, and reviews of warranty, safety, and liability issues.

### 2.3 Economic Issues

To increase profit, one needs to either increase revenue or decrease cost.
To increase revenue, one must increase price without losing units, or increase the units sold (market share) while maintaining the price. Quality affects each of these terms.

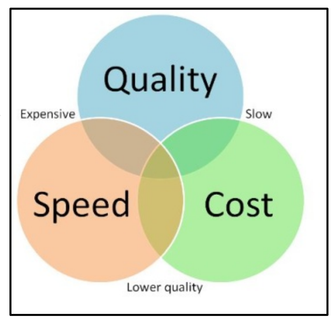


Figure 1: Relation between Quality, Speed and Cost.

#### 2.3.1 Quality and Price

Many believe that higher quality can only be produced at a higher cost; therefore, they assume that higher prices imply higher quality. This is not always the case. Research studies have found that when other factors such as brand name, store image, product features, or country of origin influence consumer perception, quality assessment is not as heavily influenced by price. Also, if managers observe that consumer perceptions of quality and purchasing decisions are positively related to price, they may command higher prices without actually increasing quality. As a result, price often bears a positive relationship to perceived quality rather than actual quality. Higher prices may actually reflect inefficiencies in production, high fixed costs, and poor quality.

Studies have shown that high product quality can allow a company to command higher prices. One power tool manufacturer discovered that higher quality tools greatly reduced the costs of maintenance and downtime for industrial users. This information became the means of convincing customers to accept a price increase. One must be cautious, however. Price premiums may also leave a firm open to competitive threats. For example, Japanese luxury car divisions such as Lexus and Infiniti claim to have equaled the quality of German counterparts at significantly lower prices and have made a significant penetration into this market.

### 2.3.2 Quality and Market Share

If a product or service meets or exceeds customer expectations, one would expect quality and market share to be positively related. This was seen in the 1970s as higher quality Japanese products made significant penetration into

Managers have a good reason to improve quality-profitability. Poor designs that do not meet customer needs, scrap and rework, and field failures all impact the bottom line. The economic impacts of quality can be easily understood from the fundamental profit equation:

**Profit = revenue - cost**
**Revenue = price x units sold**

This also has been verified by many research studies. For example, one study found that businesses that improved quality during the 1970s increased their market share five to six times faster than those whose quality declined, and three times as fast as those whose quality remained unchanged.

Studies found that businesses offering premium quality products and services usually have large market shares and were early entrants into their markets, and that a strategy of quality improvement usually leads to increased market share, but at a cost in terms of reduced short-run profitability.

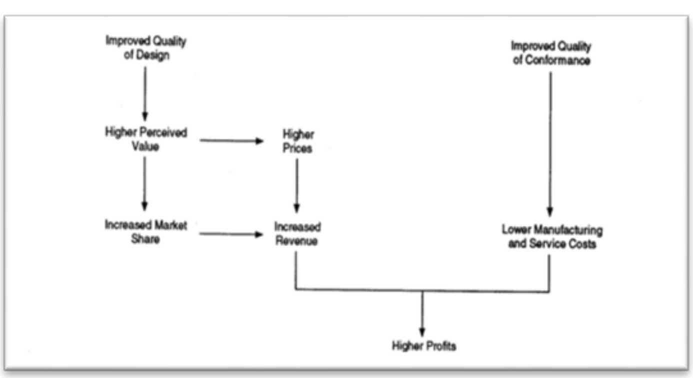


Figure 2: Quality and Profitability

### 2.3.3 Quality and Cost

From the viewpoint of quality of design, improved quality generally results in higher costs. Improved quality of design requires more costly materials, more highly skilled labor, and more expensive equipment. As argued earlier, however, improved quality of design can lead to increased revenues through higher prices and market share that can far outweigh the additional costs. On the other hand, improved quality of conformance usually results in decreased costs through savings in rework, scrap, and warranty expenses.

These relationships among quality, price, market share, and cost are summarized in figure 2. The value of a product in the marketplace is determined by the quality of design. Improved design will enhance a firm's reputation and the consumer's perception of quality, resulting in the ability to command higher prices and achieve increased market share, leading to increased revenues. Improved quality of conformance leads to lower manufacturing and service costs. The net effect of this two-pronged strategy for quality improvement is increased profits.

## 2.4 Quality, Strategic Planning and Competitive Advantage

A firm has many options in defining its long-term goals and objectives, the customers whom it wants to serve and the products and services it produces and delivers. Strategy is the approach by which an organization seeks to develop its long-term goals, policies, and plans to meet the needs of its stakeholders. In formulating a business strategy, several fundamental questions must be addressed:

- Who is your customer? What are the customer's needs and expectations?
- How can the business best serve its customers?
- What are our strengths and weaknesses? How do we compare to our competitors?
- What risks and threats could subvert future success?

*Competitive Advantage* denotes a firm's ability to achieve market superiority over its competitors. Business strategy should help a business better forecast, plan, and control its future and create a competitive advantage. A strong competitive advantage has six fundamental characteristics:

1. It is externally driven by customer wants and needs.
2. It provides significant leverage in contributing to the success of the business.
3. It provides a unique match of the organization's resources and the opportunities in the environment.
4. It is durable, lasting, and difficult for competitors to copy.
5. It provides a basis for further improvement.

6. It provides direction and motivation to the entire organization.

A business can choose to focus its efforts along several dimensions to achieve competitive advantage. These include low cost or price, outstanding service, high flexibility and variety, continuous innovation, and superior quality.
Quality is now recognized as a powerful strategic weapon. Quality is judged by the customer. All product and service attributes that connote value to the customer and lead to customer satisfaction and preference must be addressed appropriately. Value, satisfaction, and preference may be influenced by many factors throughout the customer's overall purchase, ownership, and service experiences. This includes the relationship between the company and customers-the trust and confidence in products and services-that leads to loyalty and preference. Customer-driven quality is thus a strategic concept. It is directed toward market share gain and customer retention. It demands constant sensitivity to emerging customer and market requirements, and measurement of the factors that drive customer satisfaction. It also demands awareness of developments in technology, and rapid and flexible response to customer and market requirements.

### 2.5 Multiple Dimensions of Quality

The concept of quality includes not only the product and service attributes that meet basic requirements, but also those that enhance and differentiate them from competing offerings. However, not every firm needs to compete along the same dimensions of quality. David A. Garvin (1984) observes that quality consists of eight basic dimensions:

1. Performance: A product's primary operating characteristics.
2. Features: The "bells and whistles" of the product.
3. Reliability: The probability that a product will operate properly over a specified period of time under stated conditions of use.
4. Conformance: The degree to which physical and performance characteristics of a product match pre-established standards.
5. Durability: The amount of use one gets from a product before it physically deteriorates or until replacement is preferable.
6. Serviceability: The speed, courtesy, and competence of repair.
7. Aesthetics. How a product looks, feels, sounds, tastes, or smells.
8. Perceived quality: Subjective assessment resulting from image, advertising, or brand name.

Garvin has further suggested that a company can create a niche in the marketplace by focusing only on a few of these dimensions that competitors ignore [2] [3].

## 3 OVERVIEW OF THE SYSTEM

To efficiently manage quality of products, a manufacturing system should have the following layers:

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|---|
| *ENTERPRISE RESOURCE PLANNING* |
| *MANUFACTURING EXECUTION SYSTEM* |
| *PROCESS CONTROL SYSTEM* |
| *DATA MINING TOOLS AND DATA WAREHOUSE* |

### 3.1 Enterprise Resource Planning (ERP):

#### 3.1.1 What is ERP?

An ERP system is generally considered to be a company's Information Technology (IT) data backbone application, and helps integrate business activities across multiple departments and sites (or across the entire enterprise). ERP modules range from product planning, parts purchasing, inventory control, and product distribution, to order tracking, and provides business application modules for finance, accounting, and human resources as well. Tier-one vendors such as SAP and Oracle provide full suites of ERP business applications.

ERP was introduced in the late 80s as means to integrate other enterprise functionalities. ERP systems were developed as an extension of materials requirements planning (MRP) systems. MRP, in turn, was originally developed to integrate planning and scheduling elements to the manufacturing process. Subsequently "MRP II" was introduced to incorporate the planning elements of distribution and forecast requirements to the central manufacturing location. One example would be when a software system can provide at least two other functions (as is the case if an organization has the means to integrate the requirements of both a human resources module and a financial system.)

In modern ERP systems, usage is not confined to manufacturing organizations. It is typically designed to integrate applications that traditionally would have been separate "stand alone" activities, such as product configuration control, bill of material and sales or order entry. In current ERP systems one would expect to have the ability to manage the following applications through a single database:

- Manufacturing
- Supply chain
- Financials
- Customer Relationship Management
- Human Resource
- Warehouse Management
- Business Intelligence

Determining which ERP solution best meets the needs depends to a great extent on the industry vertical space as well as the application requirements of one's organization. ERP systems are nothing more nor less than a virtual reflection of real business processes within computers and networks—

which means that the better the ERP system is, the better it reflects reality, and the less distorted a picture of one's business in virtual space. Hence, an ERP when chosen correctly is a tool that allows the company to be more efficient, increasing productivity and profits.

### 3.1.2 Different Types of ERP in Manufacturing

*DISCRETE ERP*: Discrete manufacturers assemble products from component parts. These products are made to order and can, in theory, be disassembled (cars, computers, tables).

*PROCESS ERP:* Process manufacturers, on the other hand, make products that cannot be disassembled into their component elements (spray paint, talcum powder).

*MIXED-MODE ERP*: This is used by companies who need to switch production without interrupting their operations.

*ERP FOR DISTRIBUTION:* ERP systems have sales modules, but sometimes it is more efficient to sell the finished goods to a distributor. Because they only buy and sell, these companies do not need sophisticated material requirements planning (MRP) modules, but cannot work without warehouse management, supply chain management (SCM), or retail and commerce.

*ERP FOR SERVICE:* If a company is neither producing nor selling what others produce, it is a service company. Project and expense management, back-office functionality, and others, fall into this category

### 3.1.3 WHAT DOES ERP DO?

ERP is the central control system for any organization, responsible for the interaction between different modules and subsystems. Before the evolution of ERP, manufacturing sector were running on manufacturing resource planning system. The manufacturing resource planning included all the sources in relation to the manufacturing such as material, human resource, equipment and finances. When the competitive strategy changed, ERP found the right place to give profit to this new strategy.

ERP gives a company an integrated real-time view of its core business processes, such as production, order processing, and inventory management tied together by the ERP application software and a common database maintained by a database management system. ERP systems track business resources (such as cash, raw materials and production capacity), and the status of commitments made by the business (such as customer orders, purchase orders and employee pay roll), no matter which department has entered data into the system.

It has the capacity of both finite and infinite planning capabilities. ERP solution can transform the supply chain to finance and customers. ERP software suites typically consist of integrated modules of manufacturing, distribution, sales, accounting and human resource applications. Examples of manufacturing processes supported are material requirements planning, production planning and capacity planning. Some of the sales and marketing processes supported by ERP are sales analysis, sales planning, and capacity planning, while typical distribution applications include order management, purchasing and logistics planning. Vital human resource processes, from personnel requirements planning to salary and benefits administration are supported.

## 3.2 Manufacturing Execution System (MES):

MES is a collection of tools for improving manufacturing operations through real time management of production processes, product quality and customized decision making support. MES fills the gap between the company-wide Enterprise Resource Planning system (ERP) and the control systems used to run equipment on the plant floor. It is based on the Lean production philosophy, which means it's more than a solution based on applications. It can be a complete approach for managing and controlling one's manufacturing processes in order to decrease wastes. The MES mediates between business administration (covering core functions such as sales and production planning or controlling) and the automation of the production process.

### 3.2.2 NEED FOR MES:

With the successful implementation of many ERP (Enterprise Resource Planning) systems, and the wide acceptance of plant control systems, a significant functionality gap has emerged between the two systems that are filled by the process plant equivalent of an MES (Manufacturing Execution System).

The reason for this gap is that: an ERP system will not need to deal at the specific operating instruction level; an ERP will not be dictating which tanks to use for blending, what operating conditions are required to achieve the required yield; it is unlikely that the ERP system is concerned with the specific tank location of the product.

Similarly, plant control systems require explicit instructions: line up a particular tank; optimize to a particular quality constraint; operating with the back-up pump, etc.

How are the details added to the ERP system's material requests? What business processes and support systems are required to fill in the details such that they can be passed down to the plant control systems? How are deviations to plan, schedule, or operating instructions to be handled? Many refiners are seeking a solution to these questions.

At present, this business process is largely 'manu-matic': even though there may be analytical tools to support planners, schedulers, area superintendents, etc. (LPs, schedule optimizers, blend optimizers, unit simulators and optimizers, reconciliation, etc.), the information flow is manual.

The solution is not simple. It is not sufficient to 'automate' the business process by passing electronic files between the

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applications: terminology of each system differs, neither the underlying process model, the aggregation levels rarely agree, changes are rarely coordinated, consistency between the applications are rarely verified, etc.

Thus, MES is a mode of interaction between ERP and the underlying process or plat control system in manufacturing organizations.

### 3.2.3 WHEN DOES MES COME IN?

There are three areas where ERP can fail to live up to expectations. First, investments in order-to-cash and procure-to-pay business processes have not produced the benefits expected. Oftentimes, systems that support plant applications take a back seat to ERP. The lack of manufacturing, work-in-process inventory management and plant scheduling applications resulted in lost manufacturing visibility. The supply chain is dependent on the plant but the plant is mostly invisible to the supply chain. Manufacturing, inventory and plant scheduling need to work with the supply chain in real-time to yield the visibility required for a world-class supply chain. The supply chain needs visibility into what's available, what's coming and what's possible and MES has a role in providing this information.

Another potential issue with ERP is its reliance on standard costs and fixed lead times. Actual production performance is frequently not reflected in this model. There is also a lack of timely data synchronization between ERP and plant realities. Reconciliation in the ERP world takes place on daily, weekly or even monthly intervals while the plant functions in real time. The result is two disconnected versions of the truth: one in ERP used for planning and one in production, used for scheduling and production. To optimize the supply chain and customer service, one up-to-date version is mandatory. As the drive to cut costs and maintain margins continues, ERP's financial model is not a sufficient tool to understand the realities of production costs. Accurate costing requires detailed actuals collected at the transaction level on the floor, best managed by MES.


Finally, many enterprises were searching for a lower total cost of ownership (TCO) with their ERP investments. Corporations believed ERP could be applied to the breadth and depth of manufacturing business processes. While lower TCO and the prospect of maintaining a single, omnipotent application have been seductive selling points at the corporate and plant levels, reality can be unsettling. Corporate mandates cannot improve performance if the tools and technology are not up to the task. At the plant level, ERP is often heavily customized to support manufacturing. For many of these projects, IT attempts to use ERP to accomplish objectives for which it was not designed. ERP designed to meet corporate needs, often fails to meet operational needs. "Users are better served by establishing well-defined points of integration between ERP and production systems," says Masson.

### 3.2.4 WHAT DOES MES DO?

MES is an electronic interface between personnel, equipment automation, orders, logistics, equipment and processing instructions (batch records). It is located between the company-wide Enterprise Resource Planning system (ERP) and the process control systems (SCADA/DCS). The MES mediates between business administration (covering core functions such as sales and production planning or controlling) and the automation of the production process.It's a near-real-time information broker between the transaction-based business system and the real-time plant floor environment.

MES integration connects two previously disparate systems into a continuous, coordinated system offering seamless information exchange for critical decision-making and data tracking and analysis. With an MES system in place, one can:

Arrange and download your preferred work schedule to the plant floor

Get real data history for lot tracking, yield analysis, vendor evaluation, etc.

Plant floor can manage downloaded schedule as situations require throughout the shift

Tighter quality management and audit trail

With the plant floor synchronized with the business system, you can finally start enjoying true manufacturing responsiveness — the oft mentioned agile manufacturing model

Hence, a manufacturing execution system (MES) is defined as the layer that integrates business systems with the plants control systems and is generally referred to as integration from the "shop floor to the top floor".

### 3.2.5 What does MES include?

The concept consists of several application packages that can be implemented as a complete solution for manufacturing execution, but also as areas solving specific tasks in the manufacturing process.

The areas are:

- *Order Control:* Optimizes the order stock, in every

shop floor activity, to secure the delivery of the right product at the right time. The main functions with order control are:
- Optimization of production flows
- Manning
- Line balancing
- Sequencing
- Order Monitoring

- *Product Quality Control*: The product quality control area takes care of a complete manufacturing line:
  - In Process Verification - IPV (Assembly assurance)
  - Customized Quality Control and analysis
  - Routing of transport carriers (e.g. AGV´s, conveyors…)
  - Process Quality Control: Process Quality Control produces data to be used for analysis of equipment utilization e.g.:
  - Bottlenecks
  - Mean Time Between Failure (MTBF)
  - Overall Equipment Efficiency (OEE)
  - Productivity
  - Cycle times
- *Material Control*: Material Control handles the inbound material from goods reception, delivery and ordering of new parts to the process.
- *Transport Control:* Transport Control optimizes the transports, e.g. gives the forklift driver online transport orders

## 3.3 PROCESS CONTROL SYSTEM

Process control deals with architectures, mechanisms, and algorithms for controlling the output of a specific process.

A commonly used control device called a programmable logic controller, or a PLC is used to read a set of digital and analog inputs, apply a set of logic statements, and generate a set of analog and digital outputs.

It is also referred to as Industrial Control System.

Industrial control system (ICS) is a general term that encompasses several types of control systems, including supervisory control and data acquisition (SCADA) systems, distributed control systems (DCS), and other smaller control system configurations such as skid-mounted Programmable Logic Controllers (PLC) often found in the industrial sectors and critical infrastructures. ICSs are typically used in industries such as electrical, water, oil and gas, chemical, transportation, pharmaceutical, pulp and paper, food and beverage, and discrete manufacturing (e.g., automotive, aerospace, and durable goods.) These control systems are critical to the operation of infrastructures that are often highly interconnected and mutually dependent systems.

The process-based manufacturing industries typically utilize two main processes:

*Continuous Manufacturing Processes:* These processes run continuously, often with transitions to make different grades of a product. Typical continuous manufacturing processes include fuel or steam flow in a power plant, petroleum in a refinery, and distillation in a chemical plant.

*Batch Manufacturing Processes:* These processes have distinct processing steps, conducted on a quantity of material. There is a distinct start and end step to a batch process with the possibility of brief steady state operations during intermediate steps.

The discrete-based manufacturing industries typically conduct a series of steps on a single device to create the end product. Electronic and mechanical parts assembly and parts machining are typical examples of this type of industry.

Both process-based and discrete-based industries utilize the same types of control systems, sensors, and networks. Some facilities are a hybrid of discrete and process-based manufacturing.

While control systems used in distribution and manufacturing industries are very similar in operation, they are different in some aspects. One of the primary differences is that DCS or PLC-controlled sub-systems are usually located within a more confined factory or plant-centric area, when compared to geographically dispersed SCADA field sites. DCS and PLC communications are usually performed using local area network (LAN) technologies that are typically more reliable and high speed compared to the long-distance communication systems used by SCADA systems. In fact, SCADA systems are specifically designed to handle long-distance communication challenges such as delays and data loss posed by the various communication media used. DCS and PLC systems usually employ greater degrees of closed loop control than SCADA systems because the control of industrial processes is typically more complicated than the supervisory control of distribution processes. These differences can be considered subtle for the scope of this document, which focuses on the integration of information technology (IT) security into these systems.

### 3.3.1 SCADA

SCADA systems are highly distributed systems used to control geographically dispersed assets, often scattered over thousands of square kilometers, where centralized data acquisition and control are critical to system operation. They are used in distribution systems such as water distribution and wastewater collection systems, oil and gas pipelines, electrical power grids, and railway transportation systems. A SCADA control center performs centralized monitoring and control for field sites over long-distance communications networks, including monitoring alarms and processing status data. Based on information received from remote stations, automated or operator-driven supervisory commands can be pushed to remote station control devices, which are often referred to as field devices. Field devices control local operations such as opening and closing valves and breakers, collecting data from sensor systems, and monitoring the local environment for alarm conditions.

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### 3.3.2 DCS

DCSs are used to control industrial processes such as electric power generation, oil and gas refineries, water and wastewater treatment, and chemical, food, and automotive production. DCSs are integrated as a control architecture containing a supervisory level of control overseeing multiple, integrated sub-systems that are responsible for controlling the details of a localized process. Product and process control are usually achieved by deploying feed back or feed forward control loops whereby key product and/or process conditions are automatically maintained around a desired set point. To accomplish the desired product and/or process tolerance around a specified set point, specific programmable controllers (PLC) are employed in the field and proportional, integral, and/or differential settings on the PLC are tuned to provide the desired tolerance as well as the rate of self-correction during process upsets. DCSs are used extensively in process-based industries.

### 3.3.3 PLC

PLCs are computer-based solid-state devices that control industrial equipment and processes. While PLCs are control system components used throughout SCADA and DCS systems, they are often the primary components in smaller control system configurations used to provide regulatory control of discrete processes such as automobile assembly lines and power plant soot blower controls. PLCs are used extensively in almost all industrial processes.



## 3.4 DATA WAREHOUSE AND DATA MINING

### 3.4.1 Data Warehouse

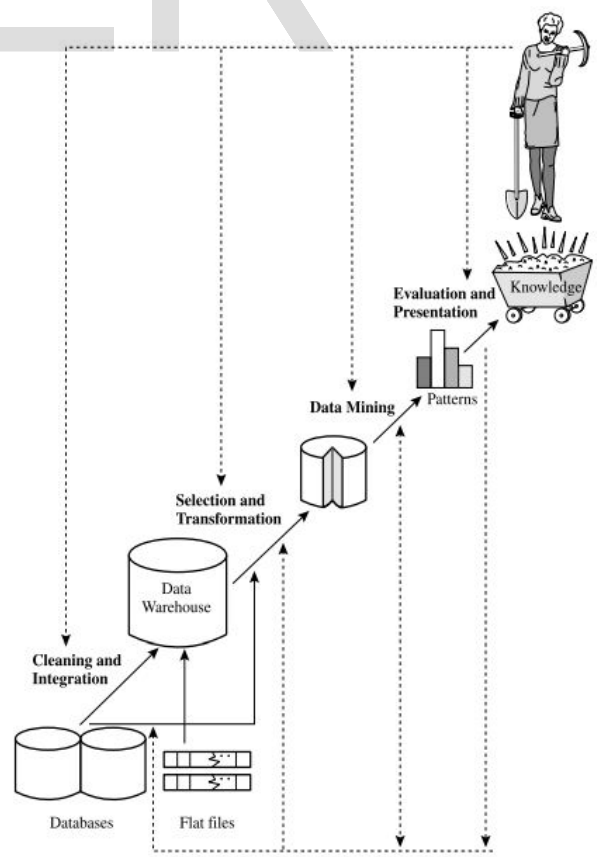
A data warehouse is a repository of an organization's electronically stored data, designed to facilitate reporting and analysis. It provides the basis on which process control and data mining tools are applied. Data warehousing arises in an organization's need for reliable, consolidated, unique and integrated analysis and reporting of its data, at different levels of aggregation. The main source of the data is cleaned, transformed, cataloged and made available for use by managers and other business professionals for data mining, online analytical processing, market research and decision support (Marakas & O'Brien 2009).

A data warehouse maintains a copy of information from the source transaction systems. This architectural complexity provides the opportunity to:

- Congregate data from multiple sources into a single database so a single query engine can be used to present data.
- Mitigate the problem of database isolation level lock contention in transaction processing systems caused by attempts to run large, long running, analysis queries in transaction processing databases. Maintain data history, even if the source transaction systems do not.
- Integrate data from multiple source systems, enabling a central view across the enterprise. This benefit is always valuable, but particularly so when the organization has grown by merger.
- Improve data quality, by providing consistent codes and descriptions, flagging or even fixing bad data.
- Present the organization's information consistently.
- Provide a single common data model for all data of interest regardless of the data's source.
- Restructure the data so that it makes sense to the business users.
- Restructure the data so that it delivers excellent query performance, even for complex analytic queries, without impacting the operational systems.
- Add value to operational business applications, notably customer relationship management (CRM) systems [4].

### 3.4.2 DATA MINING

Data mining uses information from past data to analyze the outcome of a particular problem or situation that may arise. Data mining works to analyze data stored in data warehouses that are used to store that data that is being analyzed. That particular data may come from all parts of business, from the



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production to the management. Simply stated, data mining refers to extracting or "mining" knowledge from large amounts of data

Typically, Data Mining is a step in a bigger process known as Knowledge discovery. It consists of an iterative sequence of the following steps:

1. Data cleaning (to remove noise and inconsistent data)
2. Data integration (where multiple data sources may be combined)
3. Data selection (where data relevant to the analysis task are retrieved from the database)
4. Data transformation (where data are transformed or consolidated into forms appropriate for mining by performing summary or aggregation operations, for instance)
5. Data mining (an essential process where intelligent methods are applied in order to extract data patterns)
6. Pattern evaluation (to identify the truly interesting patterns representing knowledge based on some interestingness measures)
7. Knowledge presentation (where visualization and knowledge representation techniques are used to present the mined knowledge to the user)

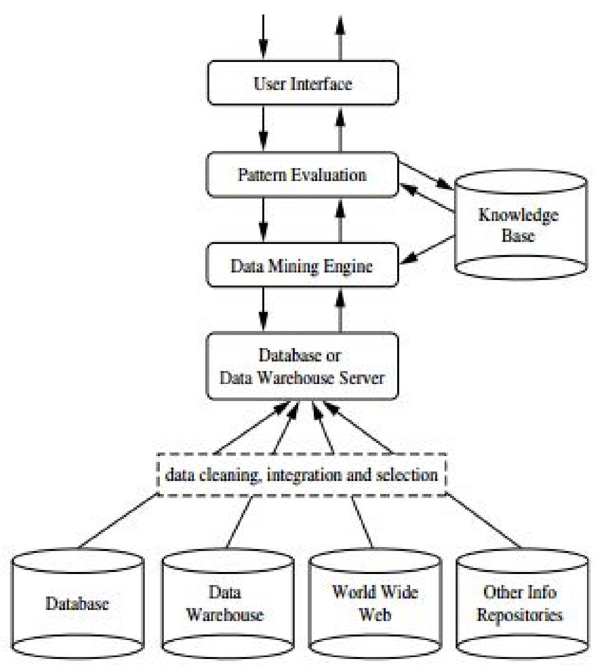
Steps 1 to 4 are different forms of data preprocessing, where the data are prepared for mining. The data mining step may interact with the user or a knowledge base. The interesting patterns are presented to the user and may be stored as new knowledge in the knowledge base.



Based on this view, the architecture of a typical data mining system may have the following major components:

1. Database, data warehouse, World Wide Web, or other information repository: This is one or a set of databases, data warehouses, spreadsheets, or other kinds of information repositories. Data cleaning and data integration techniques may be performed on the data.
2. Database or data warehouse server: The database or data warehouse server is responsible for fetching the relevant data, based on the user's data mining request.
3. Knowledge base: This is the domain knowledge that is used to guide the search or evaluate the interestingness of resulting patterns. Such knowledge can include concept hierarchies, used to organize attributes or attribute values into different levels of abstraction. Knowledge such as user beliefs, which can be used to assess a pattern's interestingness based on its unexpectedness, may also be included. Other examples of domain knowledge are additional interestingness constraints or thresholds, and metadata (e.g., describing data from multiple heterogeneous sources).
4. Data mining engine: This is essential to the data mining system and ideally consists of a set of functional modules for tasks such as characterization, association and correlation analysis, classification, prediction, cluster analysis, outlier analysis, and evolution analysis.
5. Pattern evaluation module: This component typically employs interestingness measures and interacts with the data mining modules so as to focus the search toward interesting patterns. It may use interestingness thresholds to filter out discovered patterns. Alternatively, the pattern evaluation module may be integrated with the mining module, depending on the implementation of the data mining method used. For efficient data mining, it is highly recommended to push the evaluation of pattern interestingness as deep as possible into the mining process so as to confine the search to only the interesting patterns.
6. User interface: This module communicates between users and the data mining system, allowing the user to interact with the system by specifying a data mining query or task, providing information to help focus the search, and performing exploratory data mining based on the intermediate data mining results. In addition, this component allows the user to browse database and data warehouse schemas or data structures, evaluate mined patterns, and visualize the patterns in different forms.

From a data warehouse perspective, data mining can be viewed as an advanced stage of on-line analytical processing (OLAP). However, data mining goes far beyond the narrow scope of summarization-style analytical processing of data warehouse systems by incorporating more advanced techniques for data analysis. Although there are many "data mining systems" on the market, not all of them can perform true data mining. A data analysis system that does not handle large amounts of data should be more appropriately categorized as a machine learning system, a statistical data analysis tool, or an experimental system prototype. A system that can only perform data or information retrieval, including finding aggregate values, or that performs deductive query answering in



large databases should be more appropriately categorized as a database system, an information retrieval system, or a deductive database system. Data mining involves an integration of techniques from multiple disciplines such as database and data warehouse technology, statistics, machine learning, high-performance computing, pattern recognition, neural networks, data visualization, information retrieval, image and signal processing, and spatial or temporal data analysis. We adopt a database perspective in our presentation of data mining in this book. That is, emphasis is placed on efficient and scalable data mining techniques. For an algorithm to be scalable, its running time should grow approximately linearly in proportion to the size of the data, given the available system resources such as main memory and disk space. By performing data mining, interesting knowledge, regularities, or high-level information can be extracted from databases and viewed or browsed from different angles. The discovered knowledge can be applied to decision making, process control, information management, and query processing. Therefore, data mining is considered one of the most important frontiers in database and information systems and one of the most promising interdisciplinary developments in the information technology. [5]

### 3.4.3.Enterprise Quality and Data Mining

Data warehouses populated with historical quality data serve to address questions of a more predictive nature, such as when a particular machine component is likely to break, and what combination of causes tend to lead to a malfunction in the production process. Questions of this nature require analytical modelling and/or data mining, which is a third generation of quality initiatives. Data mining is defined as the process of selecting, exploring, and modeling potentially large amounts of data to uncover previously unknown patterns for business advantage.10 In contrast, more traditional decision support techniques like online analytical processing (OLAP) usually provide descriptive answers to complex queries and assume some explicit knowledge about the factors causing the quality problem.

Analytical modelling can range from descriptive modelling using statistical analysis or OLAP to predictive modelling using advanced regression techniques and data mining methods.

While data mining can generate high returns, it requires a substantial investment. Effective data mining requires well-defined objectives, high quality data in a form ready to be mined, and generally some amount of data pre-processing and manipulation. This technology is not a fully automated process. Data mining assumes a combination of knowledge about the business/production processes and the advanced analytical skills required to ask the right questions and interpret the validity of the answers. Typically data mining is done as a team effort to assemble the necessary skills. A feedback loop to deploy data mining results into the production system ensures that a return on investment can be realized together with some clues on how to repeat this exercise for the next problem to be addressed.

Thus, a three-level quality strategy can be employed in which each level serves as a precursor to the next, and each new level generates increased knowledge about the production process and additional return of investment.

Fortunately, manufacturing data lends itself well to advanced analytics and data mining.

There is an abundance of data that are usually of high quality because their acquisition is automated. What is required is to establish a habit of storing historic data for mining analysis.

In the first generation of quality management, the quality control approach, data are typically only used for online SPC and then discarded or else archived but never analyzed.

In the second generation of quality management, the enterprise quality solution approach, data are also generated about research, suppliers, customers, and complaints. Such data are vital if the production data are to be enriched and exploited intelligently.

Decision support or data mining has been used successfully to streamline processes in manufacturing.

The following are a few examples:

- Honda Motor Company in the United States is using Weibull analyses to predict at what age or mileage various components of cars are likely to fail. The resulting information allows engineers to plan maintenance schedules and design cars that will last longer. This careful analysis and the feedback of its findings into production have enabled Honda to achieve some of the highest resale values for cars in the United States.
- A major South African power generating station experienced problems with tube failures in a re-heater. Tube failures are very costly; the material costs to replace the damaged tubes, the labor cost to perform the scope of work, the cost of lost production, and the external costs required to replace the lost production all add up. The company sought a method that would enable it to predict the potential tube failures to plan maintenance.

Data mining and multidimensional visualization techniques showed that the problem was due to a high local wear rate of a certain tube. Further investigation revealed that the inlet header disturbed the airflow, which caused the high local wear rate. A different setting of the inlet header reduced the wear significantly. Increasing the tube life by just one year delivers an estimated return on investment of 480 percent, an estimate that considers only the tube itself. Taking into account the damage and costs incurred for the re-heater and the wider effects for the entire plant, the return on investment is considerably greater.

• Data mining is used in semiconductor manufacturing to predict the likelihood that a microprocessor die will fail after packaging. It is often more cost-effective to discard defective die packages than to rework them. By pre-classifying each die with a probability of failure, the manufacturer can discard those with high probabilities very early in the assembly cycle.

This analytics-based selection process eliminates unnecessary manufacturing costs and increases the percentage of good parts exiting the assembly/test process.

• Computer hard disks are produced at mass quantities (100,000 parts per day) with a current failure rate of 1 percent. With a cost of $25 for each failure, even an improvement of 0.25 percent in the failure rate results in cost savings of $2,281,250 per year..

There are many more examples where data mining has proven to be extremely useful for process control applications, maintenance interval prediction, and production and research process optimization [6].

## 4 CONCLUSION

The success of an organization not only lies in producing quality products, but also in the effective utilization of audits to improve processes. This can be achieved primarily through sustainable innovation. Sustainable Innovtions aims to make a process:

1. *Simple:* A lengthy or complicated innovation process will lead to missed opportunities and complex implementation. The simpler the process the easier to implement.
2. *Repeatable:* Although innovation results can be valuable because they make helpful differences from tme to time, the process of making these distinctions shouldn't be any different from time to time. Innovation that can be reused is more manageable and cost optimized
3. *Flexible:* A rigid process might be good for standardized tasks but doesn't help achieve long term goals of the organizations. To keep pace with technology, it is important to create flexible systems that can be upgraded.

Information Systems play a pivotal role in every aspect of an organization. From controlling production processes to high level decision making, Information Systems not only help in maintaining quality of the products, it serves as the backbone of the whole organizational system.

## REFERENCES

[1] ANSI/ASQC A3-1978 (1978), "Quality Systems Terminology," American Society for Quality Control, Milwaukee, WI

[2] Garvin's Eight Dimensions of Product Quality". Tenner & DeToro, Total Quality Management. 2008 [last update].

[3] Quality in Manufacturing and Service, http://www.flexstudy.com/catalog/schpdf.cfm?coursenum=9529a

[4] Wikipedia

[5] Jiawei Han, Micheline Kamber, "Data Mining: Concepts and Techniques"(2-9)

[6] KPMG Consulting,"Data Mining,Quality in Manufacturing Data"( http://lyle.smu.edu/~mhd/8331f03/36516_1000.pdf)