Industrial and Systems Engineering

The Fundamentals

by

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Course 356

4 PDH (4 Hours)

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Industrial and Systems Engineering

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INDUSTRIAL AND SYSTEMS ENGINEERING

ABOUT THE COURSE

This course presents principles and practices of Industrial and Systems Engineering (IISE)[1]. The focus of IISE is Operations, namely; Operations Analysis and Design, Operations Control, and Continuous Improvement. IISE practices use science, mathematics, and engineering methods to analyze, design, and improve complex systems and operations. And, because these systems are so large and complex, IISE principles involve knowledge and skills in a wide variety of disciplines; require a broad systems perspective and the ability to work well with people.

A course about Industrial Engineering would not be complete without a brief description of why and how the profession began. The origins of Industrial Engineering[2] began in the early 1900 as part of the scientific management movement. The definition of Industrial Engineering is:

> ***Industrial Engineering is concerned with the design, improvement, and installation of integrated systems of people, material, information, equipment, and energy. It draws upon specialized knowledge and skills in the mathematical, physical and social sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems.***

Accordingly, Industrial Engineering emerged as the foundation for connecting engineering methods and economics to set quality and cost standards for delivering goods and services in business and industry. Industrial Engineers apply their knowledge and skills to set operations process standards through the use of planning, design, statistical analysis, methods engineering, interpersonal communications, quality control, computer simulation, and problem solving. This course describes the practices of IISE using a case study and examples to demonstrate the fundamentals of the profession.

KEY WORDS

Operations Analysis	Production Control	Time & Motion Study
Systems Analysis	Inventory Control	Work Measurement
Methods Engineering	Quality Control	Ergonomics

[1] Institute of Industrial and Systems Engineers, global professional society for industrial and systems engineers (https://www.iise.org)

[2] Howard P. Emerson and Douglas C.E. Naehring: Origins Of Industrial Engineering (Industrial Engineering and Management Press, 1988)

List of Figures: Industrial and Systems Engineering

CASE STUDY – ARCADIA CORPORATION

Arcadia Corporation is a case study selected to demonstrate the practices and basic applications for delivering goods and services in business and industry. IISE practices and applications will be described with examples to give the reader the depth and breadth of how industrial engineers perform their work. Manufacturing will be the focus. The case study information will consist of:

- Company History & Background
- Manufacturing Facility Employees: Chicago-metro
- Executive Organization Chart
- Manufacturing Organizations & Duties
- Chicago-metro Facility Layout
- Products and Major Operation Processes

History & Background

The ARCADIA Corporation was founded in 1955 in Dayton, Ohio. The main products of the firm were adding machines and calculators. The product line included the first hand held devices and large office desktop machines. The competition was Olivetti and Freidan.

In 1963 Texas Instruments produced and sold the first four function electronic hand held calculator. ARCADIA leased the patent and enhanced the product by adding more functions. In 1975 alliances were formed with major suppliers to expand their product lines. By 1995 the annual sales of the corporation had reached $ 7 million and the firm enjoyed a potential global market.

Much of this increase was the result of new markets established in the northeast and southern parts of the country. In 2005 a new headquarters and factory with advanced manufacturing facilities was built in the Chicago-metro area to also serve the western market. By 2015 ARCADIA sales had increased to $13 million as a result of production efficiencies.

Manufacturing Facility Employees: Chicago-metro

Employees 140
- Executive 4
- Manufacturing:
  - Factory Operations 63
  - Production Controls 21
  - Material Handling 15
- Finance & Administration
  - Finance 2
  - Accounting 3
  - Administration 10

Sales 7
Marketing 5
Customer service 10

ARCADIA ORGANIZATION CHART

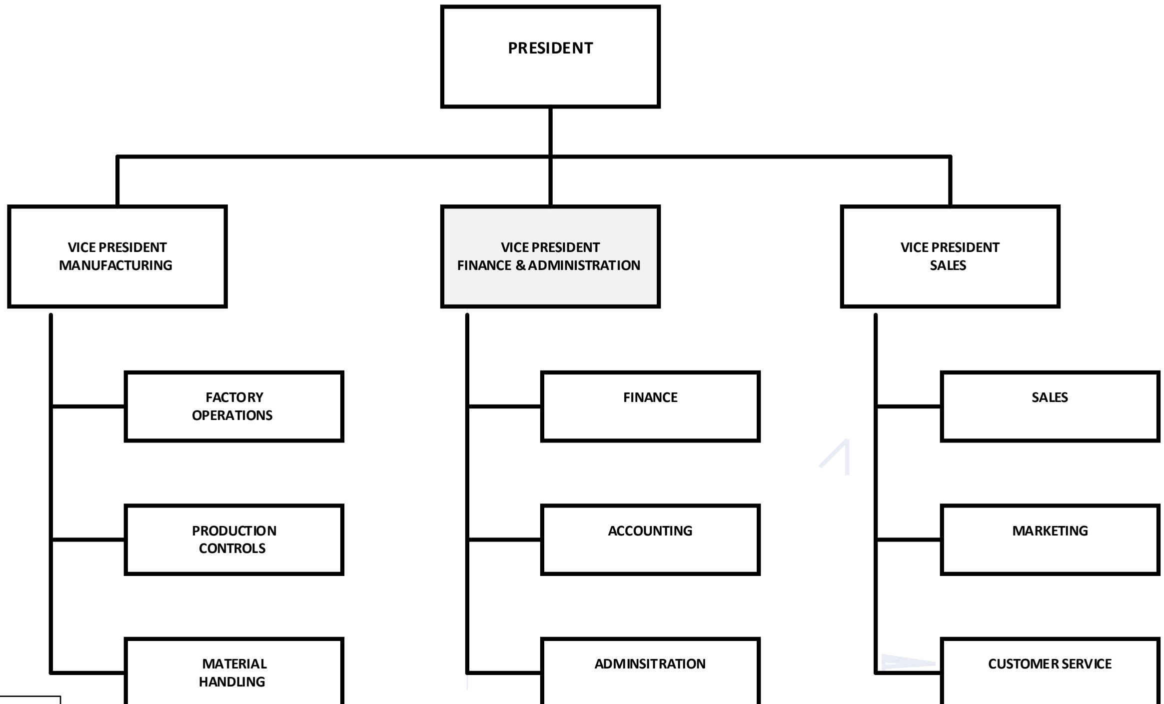

Figure 1

Manufacturing Organization and Duties

FACTORY OPERATIONS DEPARTMENT

. Plant Design Section	Design a physical plant layout to assure a safe and smooth flow of work, material and information for producing lowest cost electronic handheld and desktop calculators. Perform plant design studies to maximize effectiveness of production processes.
Plant Production Section	Manufacture plastic cases for electronic handheld calculators. Manufacture plastic cases and gear housings for desktop calculators. Manufacture plastic keys, keyboard membranes and keyboard sensors. Assemble and package electronic handheld and desktop calculators
Human Resources Section	Recruit and staff engineering and technical personnel. Recruit staff and train plant personnel. Establish employee performance and safety policies. Set compensation and benefits standards. Handle grievances, terminations and absences. Negotiate union contract.

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PRODUCTION CONTROLS DEPARTMENT

. Plant Engineering Section	Perform man-machine design studies to set quality and time standards. Establish unit cost standards and product quantity objectives. Perform operations analysis and conduct problem solving activities when quality, time and cost standards are not met.
Machine Tools & Dyes Section	Perform machine tool design studies. Specify machine tools and set standards. Monitor and maintain machine tools to standard performance. Design and fabricate dyes for plastic extrusion process.
Quality Controls Section	Set procedures to include design and functionality standards. Perform product quality and time standard inspections. Monitor manufacturing processes and collect data on product and process defects. Produce reports and defect alert notices and participate in problem solving activities.

MATERIAL HANDLING DEPARTMENT

. Receiving Section	Receive raw materials from suppliers and perform sample quality testing. Record test results. Move raw materials to warehouse bins and update inventory. Receive engineered materials from suppliers and perform quality testing. Send rejected material to Shipping Section to be returned to supplier. Move engineered materials to warehouse bins and update inventory.
Shipping Section	Receive product orders from Warehouse Section and package product orders. Ship to customers using best shipping method. Receive rejected material from Receiving Section and return to suppliers.
Warehousing & Order Section	Receive customer orders from Sales, select products from warehouse bins and send to Shipping Section. Update product inventory. Maintain inventory of raw materials and standard products using the FIFO inventory control process. Advise Factory Operations of quantity requirements and receive and store manufactured products in warehouse bins.

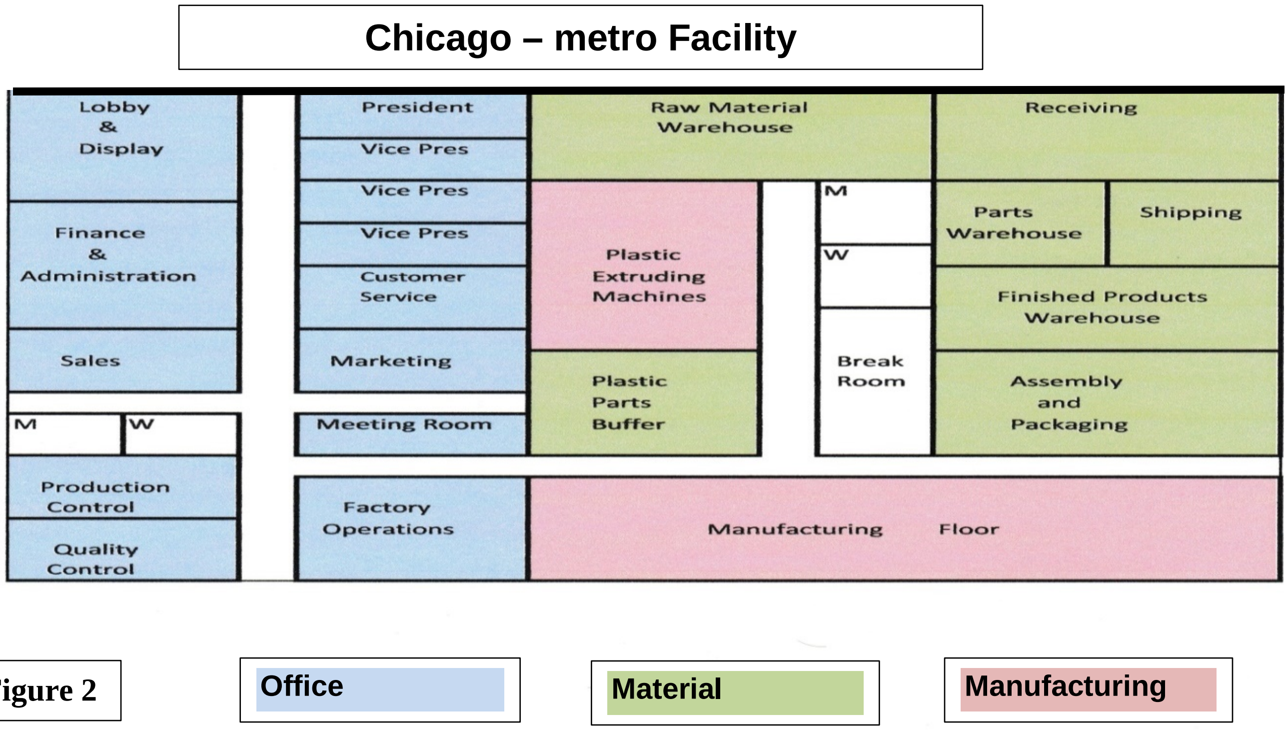

Figure 2

Products [3]

Electronic accounting, engineering, scientific handheld & desktop calculators.

Major Operation Processes

1. Receive and inspect plastic raw material, polyethylene and polycarbonate granules.
2. Receive and inspect Liquid Crystal Display (LCD) screens, Printed Circuit Boards (PCB) and lithium batteries for electronic handheld and desk calculators
3. Receive steel castings and manufacture gears for desktop paper roll calculators.
4. Extrude plastic sheets and small calculator parts for manufacturing electronic handheld and desktop calculators.
5. Manufacture plastic cases for electronic handheld calculators.
6. Manufacture plastic cases and gear housings for desktop calculators.
7. Manufacture plastic keys, keyboard membranes and keyboard sensors.
8. Assemble and package electronic handheld calculators
9. Assemble and package electronic desktop paper roll calculators
10. Order packing and shipping

[3] Appendix B Production Volume

OPERATIONS ANALYSIS AND DESIGN

Operations Analysis and Design is a practice that involves the systematic examination and design of an operations process usually by engineering, mathematical, statistical and economic methods. The theoretical basis of industrial engineering is the science of operations.[4] Successful use of this science requires the simultaneous application of three criteria: quality, timeliness and cost. The practices of industrial engineering are universally applicable for all operations in government, commerce, services, or industry. The goal of industrial engineering is to set quality and cost standards for delivering goods and services to business and industry.

To accomplish this goal industrial engineering involves "hard" as well as "soft" science to make both new and existing operations perform well. Hard science includes physical entities; tools, equipment, buildings and information such as time and space. Soft science consists of management–related factors in the work place that determines employee performance, motivation and initiative. Operations Analysis and Design practice includes the subsystems of Methods Engineering, Work Measurement, and Materials Handling.

From the Major Operation Processes: ***Number 3. Receive steel castings and manufacture gears for desktop paper roll calculators*** will be used to demonstrate the principles and applications of Methods Engineering, Work Measurement, and Materials Handling. The gear is used for desktop paper roll calculators. This is a new operation. Original gears were made of plastic. Consumer feedback determined that the plastic gear was fragile resulting in the return of many desktop paper roll calculators. A decision was made to switch to a steel gear.

Methods Engineering

Methods Engineering is concerned with the analysis and design of work methods and systems, including human effort, work place layout, tooling, equipment, technologies, plant layout and work environment.[5] The objective of Methods Engineering is to set methods standards, how the work is done. The following information and data are needed in order to conduct methods engineering subsystem activity.

- Process Description
- Process Equipment
- Process Operation

Gear

Figure 3

[4] Maynard's Industrial Engineering Handbook, fifth Edition, McGraw-Hill 2001
[5] Ibid

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Process Description: The process begins at the receiving department with the receipt of 2x5 foot rack containing 1000 steel castings, each casting weighing 3 ounces and costs $2.25 each. The racks are stored in the parts warehouse and moved to the hobbing machine work station as needed. The process continues with hobbing (cutting) a 1.77 centimeter 23 tooth gear from each steel casting.

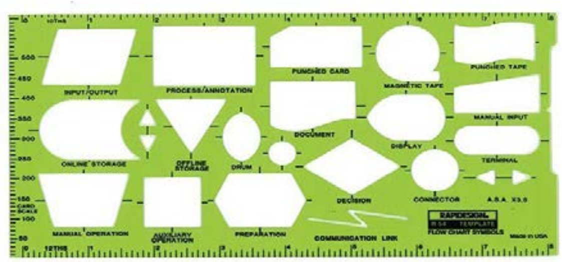
Process Equipment: High quality gear hobbing[6] machine is used with software/control technology[7].

Process Operation: A trained operator selects an individual steel casting from a tray on the2x5 foot rack, visually inspects the casting for gas porosity defects and positions the casting in the hobbing machine. If the casting has gas porosity defects the operator discards the defective casting in a recycle bin and selects another casting to position in the hobbing machine. The operator uses the touch screen on the software/control monitor to confirm casting placement, machine sequence, and cutting tool wear alert system and begins the cut. Once the cut is complete, the operator removes and inspects the gear using a manual calibration tool. If the gear meets specifications the operator places the gear on a Pre-Assembly Tray that is located on a separate 2x5 foot rack for movement to the assembly area. If the gear does not meet specifications the operator places the defective gear in a special container for quality control analysis.

Analysis and Design of Work Methods: Workflow design and analysis uses a diagram called a Process Flow Chart that shows the operation process steps and their order sequence by connecting them with arrows. Originally, process flow charts were created by hand using pencil and paper. Before the advent of the personal computer, drawing templates like the one below helped process chart makers work more quickly and gave their diagrams a more consistent look. Note, this drawing template includes computer programming symbols as well as physical and decision making process steps. Template symbols and diagrams have changed over time based on software vendors. However, the rectangular box which represents an operation and the diamond which represents a decision have remained the same

Drawing Template

Figure 4



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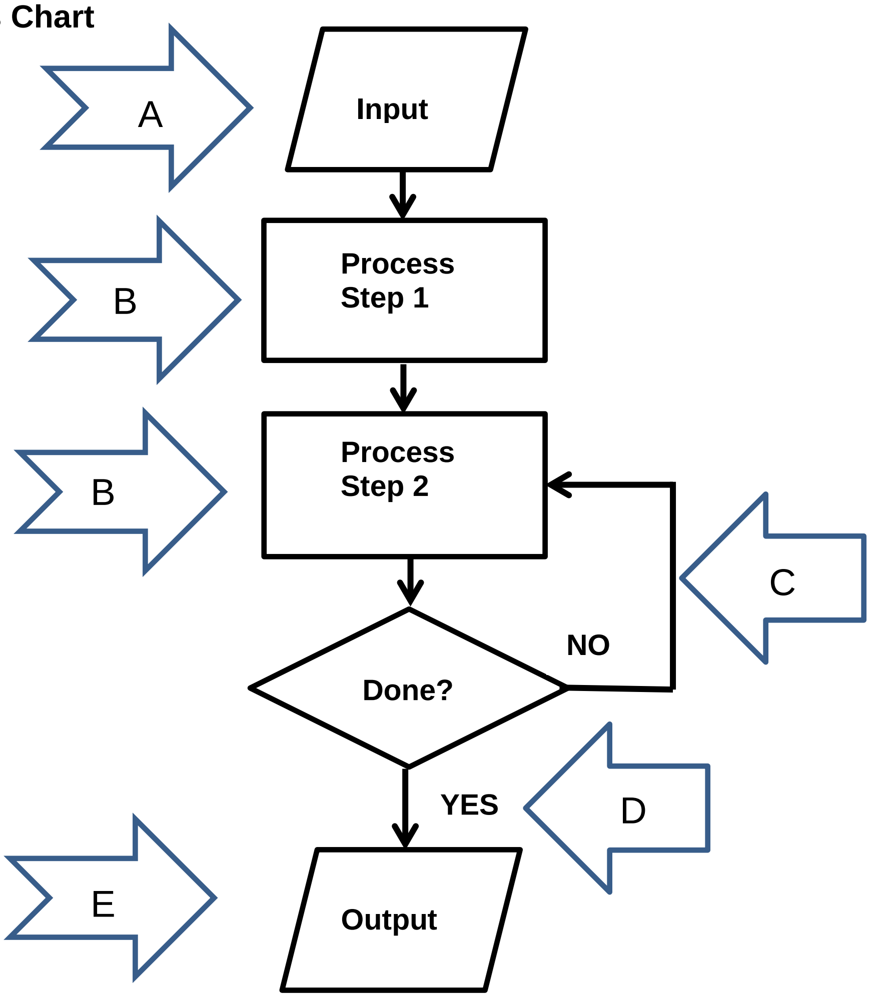
[6] Hobbing Machines, LEIBHERR, LC 80-180
[7] LHGe@rTec®

Simple Flow Process Chart

Figure 5



The simple process chart above is an example of boxes and arrows connected to show process steps:

- ***A.*** Process Input,
- ***B.*** Perform Process Step 1 & Process Step 2,
- ***C.*** Is Process Step 2 done? If NO return to Process Step 2,
- ***D.*** Is Process Step 2 done? YES,
- ***E.*** Proceed to Process Output.

Below is a Gear Cutting Operation Process Chart.

Gear Cutting Operation Process Chart

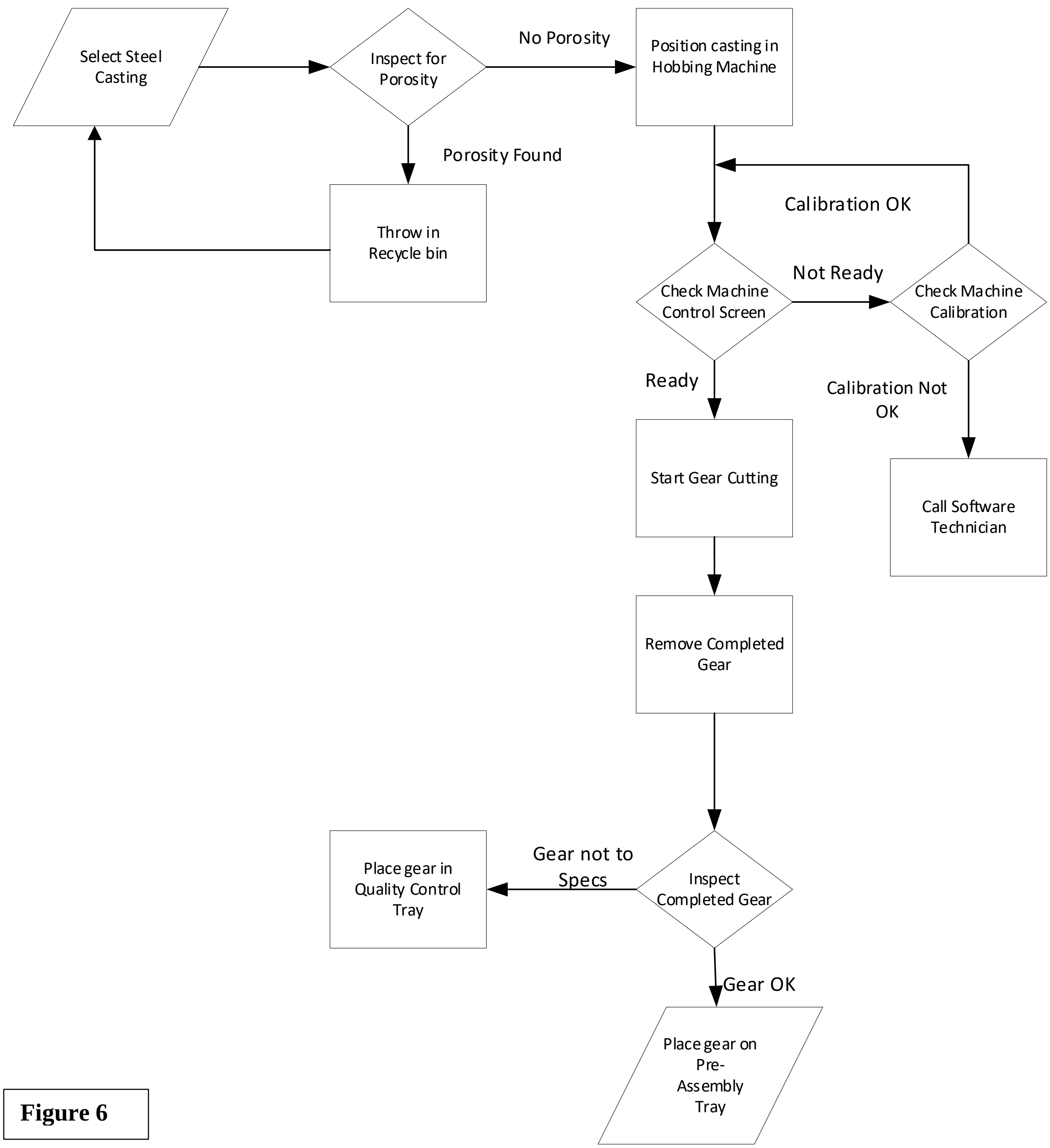


Figure 6

Work Measurement

Work Measurement is concerned with the methods used to establish the standard time for an average qualified worker to perform a specified task using a prescribed method. The objective of Work Measurement is to set production rates allowing time for personal needs, fatigue and delay. Standard times have traditionally been developed in three major ways.[8] Time study is the first way to determine time standards using direct observation and measurement. Time study[9] is the preferred method and has provided effective and accurate time standard results. Estimation is the second way time standards have been developed. The common method of estimation is the use of historical data of similar operations. The third way of setting time standards is through the use of standard data systems typically referred to Predetermined Time Systems (PTS). PTS methodology is beyond the scope of this course.

Figure 7

Early industrial engineers used a stopwatch (Figure 7) with the operations listed on a clip board. The industrial engineer observed the operator at the work station and recorded the time for each operation. While the process of observation has not changed, today's industrial engineer has a tablet with a touch screen that displays the operations list and uses a macro application (TimeCat 3.9 Google Chrome) to record the observations. The number of observations is determined by the following statistical formula. The formula is based on using the arithmetic mean of prior operation's time studies.

Number of Observations = <u>4 times the standard deviation squared of prior time studies</u>
Divided by .25 margin of error squared

The standard deviation of prior time studies is .87
The margin of error is set at ± .25

$$48 = 4 \times (.87) \times (.87) / (.25) \times (.25)$$

Therefore, 48 observations were made for each operations listed on the spread sheet below.

Note:

- Operation # 3- Throw in recycle bin, occurred 12/48 times = .25 Cycle
- Operation # 7- Stop hobbing machine operation, call technician, occurred 3/48 = .06 Cycle
- Operation # 11- Place gear not to specs in quality control tray, occurred 4/48 = .08 Cycle

[8] Maynard's Industrial Engineering Handbook, fifth Edition, McGraw-Hill 2001
[9] TimeCat 3.9 Google Chrome: Time study App provides qualitative and quantitative approach to accurate data collection. info@timecat.org

Time Study Cycle Worksheet -Gear Cutting 48 Observations					
No.	**Operation**	**48 Observations Seconds**	**Average Time**	**Cycle**	**Normal Time**
1	Select steel casting from tray	240	5	1	5
2	Inspect steel casting for porosity	480	10	1	10
3	Throw in recycle bin	240	5	0.25	1.25
4	Clamp steel casting in hobbing machine	480	10	1	10
5	Check hobbing machine touch screen for ready light	144	3	1	3
6	Touch screen to confirm operating software update	144	3	1	3
7	Stop hobbing machine operation, call technician	336	7	0.05	0.35
8	Touch screen to start hobbing machine gear cut	240	5	1	5
8A	Hobbing machine cutting gear	14400	300	1	300
9	Remove completed gear from hobbing machine	720	15	1	15
10	Inspect Completed gear with manual calibration tool	1440	30	1	30
11	Place gear in quality control tray	144	4	0.08	0.32
12	Place completed gear on Pre-Assembly tray	240	5	1	5
	Total		402		388

Setting an operation standard time from a time study involves using the following formula.

Standard Time = Normal Time (1 + PFD[10])

Gear Cutting Operation Standard Time = 388 (1 +.15) Seconds

Gear Cutting Operation Standard Time = 394 Seconds

The production rate is set at 9 units per hour.

[10] Maynard's Industrial Engineering Handbook, fifth Edition, McGraw-Hill 2001
PFD is an Allowance given for Personal, Fatigue, Delay time approximately 10% to 15%

Material Handling

Material handling is concerned with the movement of materials using manual, semi-automated and automated equipment. It involves the protection, storage and control of materials throughout their manufacturing, warehousing, distribution, consumption and disposal.[11] The objective of Material Handling is to set a standard flow of materials to support the manufacturing operation. Material handling plays an important role in manufacturing and logistics. It is an integral part of production systems design because the efficient flow of material between operations is heavily dependent on the arrangement of the production's physical layout. Manual handling refers to the use of a worker's hands to move individual items or containers by lifting, placing, lowering, filling, emptying or carrying them. The science of ergonomics considers how humans behave physically and psychologically in relation to particular environments, products or services. Ergonomics for manual material handling is concerned with worker safety and health and the efficient flow of material. NIOSH (National Institute for Occupational Safety and Health) 1991 Revised Lifting Equation is an ergonomic example for providing worker safety during a lifting operation.[12]

The Gear Cutting process begins at the receiving department with the receipt of 2x5 foot rack containing 500 steel castings. The racks are stored in the parts warehouse and moved to the hobbing machine work station as needed.

Steel Castings

A trained operator selects a steel casting from a tray on the2x5 foot rack, visually inspects the casting for gas porosity defects and positions the casting in the hobbing machine. If the casting has gas porosity defects, the operator discards the defective casting in a recycle bin and selects another casting to position in the hobbing machine.

If the gear meets specifications, the operator places the gear on a Pre-Assembly Tray that is located on a separate 2x5 foot rack for movement to the assembly area.

Finished Gears

Figure 8

[11] "Material handling"(http://www.mhi.org/fundamentals/material handling) MHI. Retrieved 2014-10-02

[12] Waters, T.R. (1994) Applications Manual for the Revised NIOSH Lifting Equations, Cincinnati, OH Centers for Disease Control and Prevention.

OPERATIONS CONTROL

Operations control is concerned with the design and control of the production processes, material inventory and product quality. *Production Control* provides for an orderly flow of product to ensure that at the different stages of production the produced items are of the right quality, at the right time with minimum effort and cost. *Inventory Control* provides that the right material is of the right quality to be provided at the right time, with minimum effort and cost. *Quality Control* establishes the systems to inspect, measure and monitor the quality of inventory, manufacturing activities and product quality.

Early industrial engineers used manual methods to design the orderly flow of product and provide the right material to ensure that at the different stages of production the produced items are of the right quality, at the right time with minimum effort and cost. However, since that time the processes of *Production Control* and *Inventory Control* have changed. What has changed is the role of the computer used to manage inventory and support manufacturing activities. Computer software technology currently provides time and cost saving benefits to control inventory and production[13]. Essentially the industrial engineers' manual methods for *Production Control* and *Inventory Control* have been programmed into computer systems that can perform faster and with more accuracy to manufacture product. Moreover, computer–aided manufacturing equipment has evolved into Robotics and Integrated Manufacturing (RIM) that has resulted in increased production and lower costs by significantly reducing operator time and effort.

Operations Control for Chicago–metro facility departments will show the general production flow. The discussion for this course will focus on the Major Operations Processes that support the basic practices of industrial engineering. Product detail connected with the electronic desktop paper roll calculator will be used to demonstrate the application of *Production Control* and *Inventory Control* without reference to automated software systems. Computer software systems and Robotics and Integrated Manufacturing are beyond the scope of this course and will not be addressed.

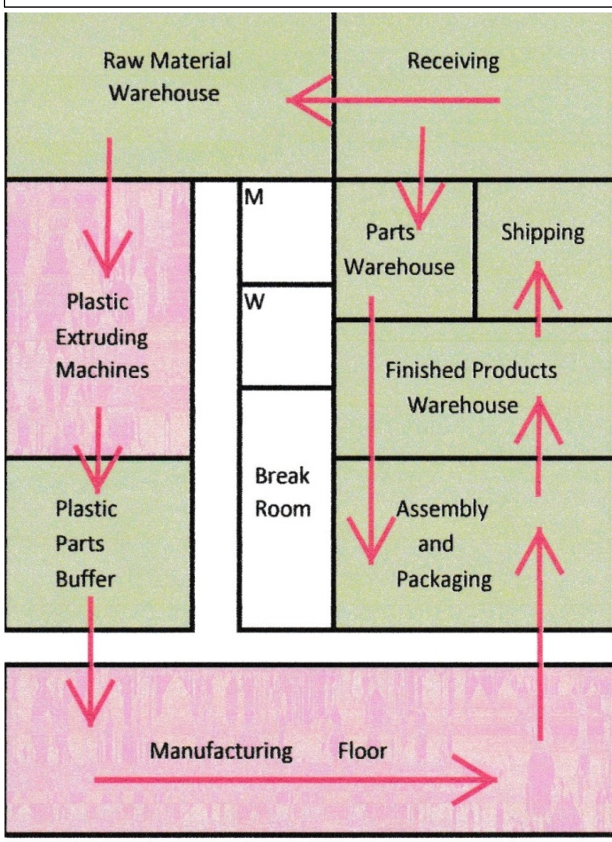
Figure 9

[13] Appendix F –Production Control Software

PRODUCTION CONTROL

The objective of production control is to regulate and schedule the various operations of the production processes. Effective production control requires that the physical layout of machinery and equipment is positioned for safe and smooth flow of material, work, and information for manufacturing the product. This provides for an orderly flow of product to ensure that at the different stages of production the produced items are of the right quality, at the right time with minimum effort and cost. Below is an arrow diagram of the Chicago–metro facility departments showing the general production flow.

DEPARTMENT FLOW	MAJOR OPERATION PROCESS



1. Receive and inspect plastic raw material, polyethylene and polycarbonate granules.
2. Receive and inspect Liquid Crystal Display (LCD) screens, printed circuit boards (PCB) and lithium batteries, miscellaneous wire and hardware for electronic handheld and desk calculators
3. Receive steel castings for cutting gears for desktop paper roll calculators.
4. Extrude plastic sheets and small calculator parts for manufacturing electronic handheld and desktop calculators.
5. Manufacture plastic cases for electronic handheld calculators.
6. Manufacture plastic cases and gear housings for desktop calculators.
7. Manufacture plastic keys, keyboard membranes and keyboard sensors.
8. Assemble and package electronic handheld calculators
9. Assemble and package electronic desktop paper roll calculators
10. Order packing and shipping

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A more detailed production flow of an electronic desktop paper roll calculator is shown in the chart below. The chart is divided into three columns: Department, Material/Product Component and Activity/Operation. The first column identifies the Department. The second column describes the Material/Product Component. Material is unfinished product components such as plastic raw material and steel castings. Product Component identifies finished product parts such as LCD screens, processor chips and lithium batteries. The third column describes what is done to the material or product component. In the case of the **Receiving** department, all the material and product components are stored in the various warehouses. Another example such as the **Plastic Extruding Machines** department, the operation uses the plastic raw material to extrude (produce) plastic sheets and small calculator parts. And, in another example the **Manufacturing Floor** department uses the steel castings to cut steel gears for desktop paper roll calculators.

PRODUCTION FLOW OF ELECTRONIC DESKTOP PAPER ROLL CALCULATOR

Department	Material/Product Component	Activity/Operation
Receiving Level 1	Receive & inspect plastic raw material, polyethylene and polycarbonate granules. Receive and inspect Liquid Crystal Display (LCD) screens, Printed Circuit Boards (BCP, lithium batteries, miscellaneous wire and hardware for electronic desktop calculators. Receive steel castings for gears in desktop paper roll calculators. Receive printed cardboard packing boxes for various products	Store raw material in Raw Materials warehouse. Store LCD screens, PCBs and lithium batteries in Parts Warehouse Store steel castings in Raw Materials warehouse. Store printed cardboard packing boxes in Finished Products Warehouse.
Plastic Extruding Machines Level 2	Receive & inspect plastic raw material, polyethylene and polycarbonate granules.	. Extrude plastic sheets for various plastic calculator parts for manufacturing electronic desktop calculators.[14]
Plastic Parts Buffer Level 2	Receive extruded plastic sheets for various plastic calculator parts for manufacturing electronic desktop calculators.	Store extruded plastic sheets for various plastic calculator parts for manufacturing electronic desktop calculators.

[14] Appendix C

Department	Material/Product Component	Activity/Operation
Manufacturing Floor Level 3	Receive plastic sheets for various plastic calculator parts for manufacturing electronic desktop calculators. Receive steel castings for desktop paper roll calculators. Receive printed circuit boards (PCB)	Manufacture plastic packaging containers and plastic cases for desktop calculators.[15] Manufacture plastic keys, keyboard membranes and keyboard sensors. Cut steel gears for desktop paper roll calculators. Test printed circuit boards (PCB)[16]
Assembly and Packaging Level 4	Receive plastic packaging containers, plastic cases and gear housings for desktop calculators. Receive plastic keys, keyboard membranes and keyboard sensors. Receive steel gears and plastic parts for desktop paper roll calculators. Receive tested printed circuit boards (PCB) Receive lithium batteries	Assemble desktop paper roll calculators. Insert lithium batteries, test calculator operation, remove batteries and place in product packaging container section for batteries. Assemble paper roll gear housing. Test paper roll operation. Place assembled desktop paper roll calculator in product packaging container.
Finished Products Warehouse Level 5	Receive desktop calculator in product packaging container. Select appropriate printed cardboard packing box for desktop calculator from inventory.	Insert product packaging container with assembled desktop calculator in the appropriate printed cardboard packing box for desktop calculator. Mark and store for shipping

[15] Appendix D
[16] Appendix E

INVENTORY CONTROL

The objective of inventory control is to provide an orderly flow of material to ensure that at the different stages of production that the right quantity of material is provided at the right time, is of the right quality with minimum effort and cost. Inventory is the stock of any item or resource used in the manufacture of a product. Manufacturing inventory is classified into raw materials, component parts, supplies, and work in process. When controlling inventory, it is important to distinguish between dependent and independent demand and usage.

In dependent demand, the need for any one item is a direct result of the need for some other item. For example, Arcadia produces 2,700 electronic calculators per day, accordingly, 2,700 LCD screens are needed. The number of LCD screens is dependent on the production levels and not derived separately. Independent demand, the demands for various items are unrelated but meet some external demand requirement. The demand of electronic calculators is independent because it comes from external sources, namely the sale of products; i.e. hand held electronic calculators, desktop electronic calculators[17]. Effective inventory control for Arcadia's manufacturing processes involves a combination of the Reorder Point (ROP) system for dependent inventory items and Material Requirements Planning (MRP) for independent inventory items.

Dependent Demand Inventory

The Reorder Point (ROP) system uses a level of inventory that triggers an action to replenish that particular inventory stock. It is a minimum amount of an item which a firm holds in stock, such that, when stock falls to this amount, the item must be reordered. The following steps are used to calculate the reorder point.

1. Multiply maximum daily usage by maximum lead time in days
2. Multiply average daily usage by average lead time in days
3. Calculate the difference between the two to determine reorder point

Inventory Item	Level	Max Daily Usage	Max Lead Time	Ave Daily Usage	Ave Lead Time	Reorder Point
LCD Screens	1	3500	7	2700	5	11,000
PCB Boards	1	2800	15	2700	10	15,000
Lithium batteries	1	2800	5	2700	3	5,900
Steel Castings	1	175	20	140	10	2,100

[17] Production and Operations Management Manufacturing and Services, Eighth Edition 1998 Irwin /McGraw-Hill

The quantity to be reordered is based on a formula that minimizes storage costs and ordering costs called Economic Order Quantity (EOQ). EOQ is the order quantity that minimizes the total holding and ordering cost for a year. There are five principle elements to be considered in selecting the proper formula. Since the operating manufacturing environment can contain many assumptions, a large variety of formulas exist. As long as the formula is derived from assumptions that match the operating manufacturing environment, it will produce useful results.

For Arcadia Manufacturing the simplest case is to assume that:
EOQ = the quantity of items delivered to stock all at the same time.
U = annualized usage in stock items per year will continue at the same rate for an indefinite time.
C = the cost in dollars per item is the same at any time in the future for any reasonable quantity.
A = acquisition cost in dollars per order applies to each item individually.
S = the storage cost is the value of the minimum stock as a percent of the total inventory value.

$$EOQ = \sqrt{\frac{2 \times U \times A}{S \times C}}$$

U = Annual Usage
A = Acquisition Cost
S = Storage Cost in %
C = Item Cost

The following table presents the five principle elements for Arcadia dependent inventory items using the Reorder Point (ROP) system.

Inventory Item	Annual Usage	Acquisition Cost	Storage Cost -%	Item Cost	EOQ
LCD Screens	680,000	$15	.14	$6.93	4,587
PCB Boards	680,000	$25	.21	$7.59	4,620
Lithium batteries	680,000	$5	.04	$3.67	6,808
Steel Castings	35,280	$10	.01	$1.83	6,210

Independent Demand Inventory

Independent demand is defined as the demand for various items that are unrelated but meet some external demand requirement. Independent demand comes from external sources, namely the sale of products; i.e. hand held electronic calculators, desktop electronic calculators. Independent demand uses Material Requirements Planning system for controlling inventory. Material Requirements Planning (MRP) is a production planning, scheduling, and inventory control system used to manage manufacturing processes.

MRP consists of three major steps:

1. Identify quantity requirements using “Bills of Material”
2. Determine quantity on hand from inventory records
3. Purchase needed quantity based on forecast if not available in inventory

Identifying quantity requirements is also concerned with minimizing the cost of inventory. While ROP focus is on minimum stock level and economic reorder quantity, MRP focus is on reorder strategy using several methods to identify quantity requirements. Product forecasting models and a variety of statistical methods are used to supply the manufacturing process with material and parts. Essentially, MRP strategies work backwards. Product planning begins at the end, with the finished product. Every finished product has a standard list of materials, components and subassemblies called a Bill of Material. Below is an example of the Bill of Material for a Desktop Paper Roll Electronic Calculator for Engineers. Note, Part Number 4000 the Printed Circuit Board (ENG) is designed for engineering calculations and formulas. Also, Printed Circuit Boards are received at Level 1 (Receiving Department) but are tested at Level 3 (Manufacturing Department).

BILL OF MATERIAL: DESKTOP PAPER ROLL CALCULATOR- ENG

Part No	Description	Quantity	Unit of Measure	Level
103	Packing Box	1	Each	1
1003	Packaging Container	1	Each	3
2001	Plastic Case - Top	1	Each	3
2002	Plastic Case - Bottom	1	Each	3
3000	Plastic Keys	1	Each	3
4000	Printed Circuit Board (PCB) /wire (ENG)	1	Each	1/3
4001	Liquid Crystal Display Screen (LCD)	1	Each	1
5000	Gear Housing Assembly	1	Each	3
4002	Lithium Batteries	4	Each	1
2003	Mini Screws Stainless	6	Each	1
2004	Mini Screws Black	4	Each	1

Industrial and Systems Engineering

The example below is the inside and outside view of a Sharp electronic desktop paper roll calculator; similar to Arcadia's Desktop Paper Roll Electronic Calculator for Engineers.

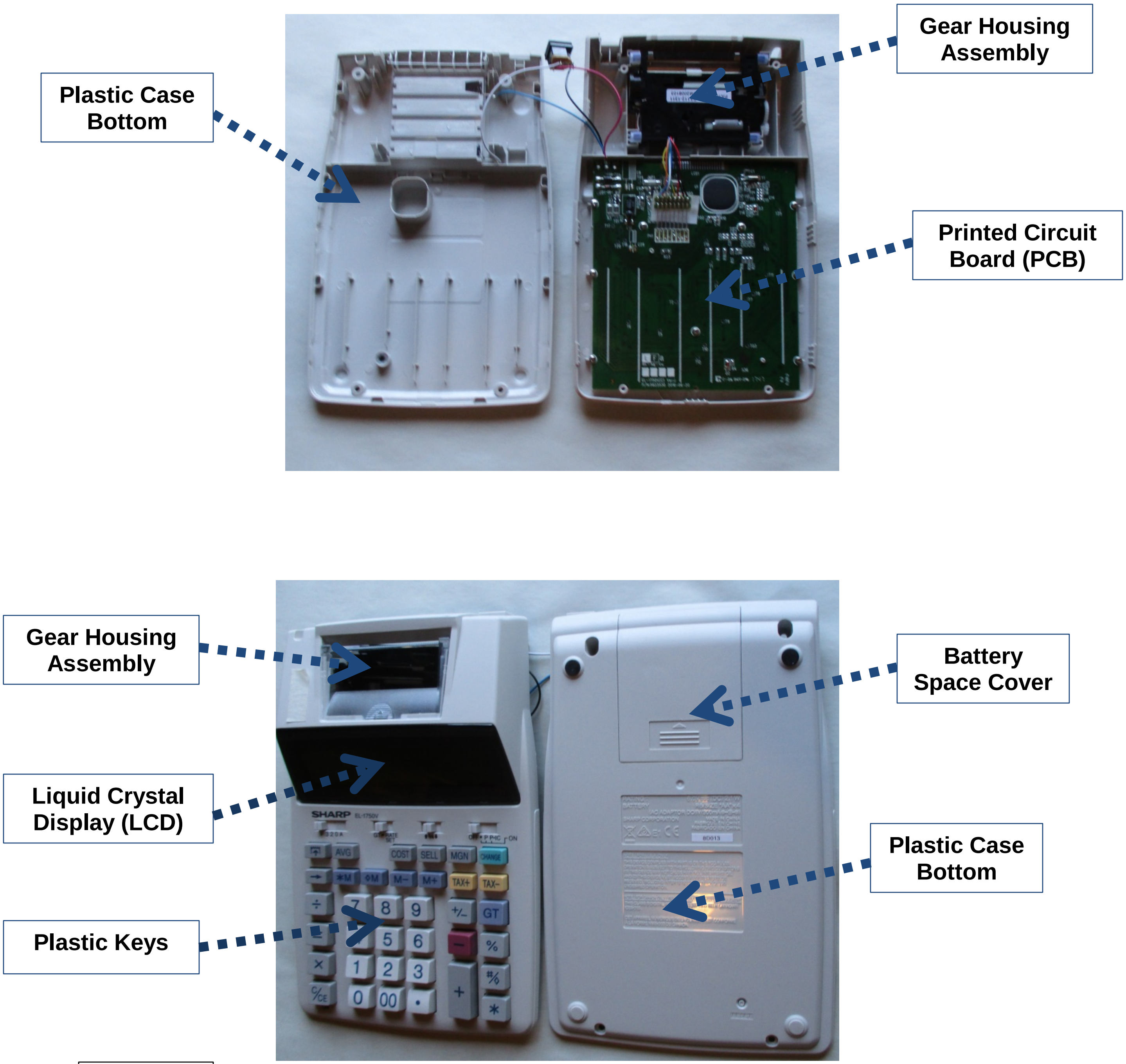


Figure 10

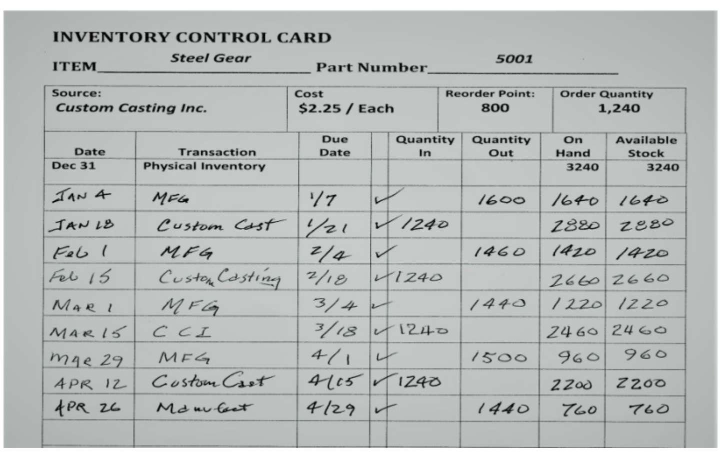
Industrial and Systems Engineering

Production planning is a function of forecasting sales. The chart below shows Arcadia's annual sales forecast for the electronic desk top calculator with paper roll function.

Electronic Desk Top Calculators with Paper Roll

Type	Volume	Price	Revenue	Cost	Profit[18]
Accounting	10,000	$70	$710,000	$648,230	$61,770
Engineering	10,000	$70	$710,000	$648,230	$$61,770
Scientific	20,000	$70	$1,420,000	$1,296,460	$123,540
Total	40,000		$2,840,000	$2,592,920	$247,080

The production rate for the electronic desk top calculator with paper roll is scheduled for 140-160/day. Inventory in stock to supply the production of 140-160 needs to be available and delivered to the appropriate stage of production to fulfil the schedule. For example, a minimum of 160 steel gears must be available and delivered to assemble the Gear Housing Assembly to support that day's production in the Assembly and Packaging Department. Inventory records, "stock status" must be checked to determine quantity at hand. In the early years, Material Control Cards were used to record "stock status." Below is an example of an Inventory Control Card showing the "stock status" of inventory for the steel gear. The information identifies the item, source, and cost, reorder point, reorder quantity and in and out transactions are posted by order date and date due.



INVENTORY CONTROL CARD

ITEM *Steel Gear* Part Number *5001*

Source:	Cost	Reorder Point:	Order Quantity
Custom Casting Inc.	$2.25 / Each	800	1,240

Date	Transaction	Due Date		Quantity In	Quantity Out	On Hand	Available Stock
Dec 31	Physical Inventory					3240	3240
JAN 4	MFG	1/7	✓		1600	1640	1640
JAN 18	Custom Cast	1/21	✓	1240		2880	2880
Feb 1	MFG	2/4	✓		1460	1420	1420
Feb 15	Custom Casting	2/18	✓	1240		2660	2660
MAR 1	MFG	3/4	✓		1440	1220	1220
MAR 15	CCI	3/18	✓	1240		2460	2460
MAR 29	MFG	4/1	✓		1500	960	960
APR 12	Custom Cast	4/15	✓	1240		2200	2200
APR 26	Manufact	4/29	✓		1440	760	760

Figure 11

[18] Profit Margin 0.087%

QUALITY CONTROL

Quality control is a procedure used in manufacturing to prevent defects in manufactured products. The objective of quality control is to establish quality and safety standards for products for the consumer market. Similar to industrial engineering, the profession of quality management[19]also had its origins as part of the scientific management movement in early 1900. Today Total Quality Management (TQM) has emerged into a sophisticated global presence.[20] Quality control is only a part of TQM. It began by developing tools to support the quality and safety of manufactured products. Industrial engineering includes the practice of quality control. Quality control is typically associated with statistical approaches that consist of seven key tools; 1 Check Sheets 2 Pareto Charts, 3 Cause-and-Effect Diagrams, 4 Histograms, 5 Scatter Diagrams, 6 Run Charts, and 7 Control Charts.

For beginning industrial engineers the fundamental tools are Check Sheets, Pareto Charts, and Cause-and-Effect Diagrams. Another important tool, Flow Chart, has been adopted from the industrial engineering tool kit. The Flow Chart shows how the operation causing the defect actually works and it is used for analysis to arrive at the Root-Cause.

Arcadia's Chicago Metro factory operations examples will be used to demonstrate the fundamental quality control tools for industrial engineers. However, before these operating examples are presented it is important to describe the parameters, namely the definition and standard practice of Arcadia's quality control procedure. Manufacturing quality control procedure involves the following steps:

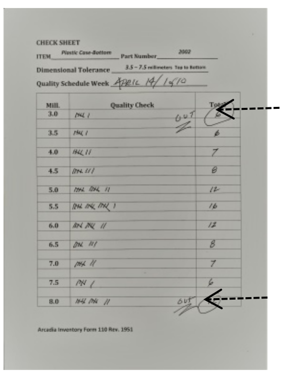
Step	Procedure Definition	Standard Practice
1	Set design and functionality product standards	Exterior design based on industry competition. Functionality based on ease of operation and value engineering.
2	Determine measurement and tolerances to meet product standards	Consumer feedback and Zero Defects in manufacturing based on 95% tolerance.
3	Establish criteria for when, how, and the number of products are inspected	Periodic scheduled inspections recorded on Check Sheets using attribute and variable data for specific products
4	Record inspection data	Use Check Sheets, Pareto Charts, Cause-and-Effect Diagrams
5	Analyze inspection data and take corrective action as necessary	Use Flow Charts, Pareto Charts, Cause-and-Effect Diagrams for analysis to determine action

[19] David L. Goetch and Stanley Davis, Quality Management for Organizational Excellence, Seventh Edition Introduction to Total Quality, Pearson 2013
[20] Ibid

The following pages present Arcadia's Chicago Metro factory operations examples using the fundamental tools of Check Sheets, Pareto Chart, Cause-and-Effect Diagram, and Flow Chart.

CHECK SHEET

Early industrial engineers could be seen walking the factory floor armed with their clip board and stop watch. They are on a routine quality inspection schedule. Their clip board holds a form called the Check Sheet. However, the Check Sheet can take any form. The only rules are that data collection must be the equivalent of entering a check mark and that the displayed data must easily be translated into useful information. The purpose of the Check Sheet is to collect data that will be used to monitor all manufacturing operations to determine if they meet product quality standards. For example, part number 2002 Plastic Case – Bottom for all electronic calculators is designed with a dimensional tolerance of 3.5 to 7.5 millimeters top to bottom. This design requirement is necessary for the Plastic Case – Bottom to snap in place with Plastic Case-Top. The Check Sheet for this inspection would look like this:



CHECK SHEET

ITEM Plastic Case-Bottom Part Number 2002

Dimensional Tolerance 3.5 – 7.5 millimeters Top to Bottom

Quality Schedule Week April 14/1410

Mill.	Quality Check	Total
3.0	OUT	6
3.5		6
4.0		7
4.5		8
5.0		12
5.5		16
6.0		12
6.5		8
7.0		7
7.5		6
8.0	OUT	[illegible]

Arcadia Inventory Form 110 Rev. 1951

The quality check identified
18 / 100 checks
out of tolerance limits

3.5 to 7.5 mm

Figure 12

This type of Check Sheet is used for 'variable data' type inspections. Variable data inspections have design tolerances similar to the Plastic Case – Top. The other type of inspection is called 'Attribute' inspection. Attribute inspection is also known as 'Go-No-Go' inspection. The item and/or unit inspected is either acceptable or defective. The inspection of the steel gear must be to exact specifications or it ends up in the defective tray. The inspection Check Sheet used merely records the number of defective gears on a weekly basis and provides this information to Quality Control. The record shows gears not to specification at 30/100. Both these inspection results and others are displayed in the Pareto Chart.

Today's industrial engineers walk the factory floor with a tablet. Check Sheet data are transmitted using Wi-Fi to the Quality Control Office and they walk in to find a finished Excel Pareto Chart at their printer.

PARETO CHART

The Pareto Chart is a statistical tool that is used to select the most critical operating problem that does not meet standards and needs to be corrected. The term used to describe an operations process that does not meet standards is called a defect. Defects are manufacturing process steps that do not meet quality standards. Visual and/or automated inspections identify the number of times an operation process does not meet standards. These defects are recorded on Check Sheets and plotted in bar chart format called the Pareto Chart. The chart shows the number of defects. Figure 2, below, is an example of a Pareto Chart from ARCADIA's manufacturing and warehouse floor. It shows several operation processes that have not met standards. The operation with highest number defects is selected for analysis, **gear not to specification.**

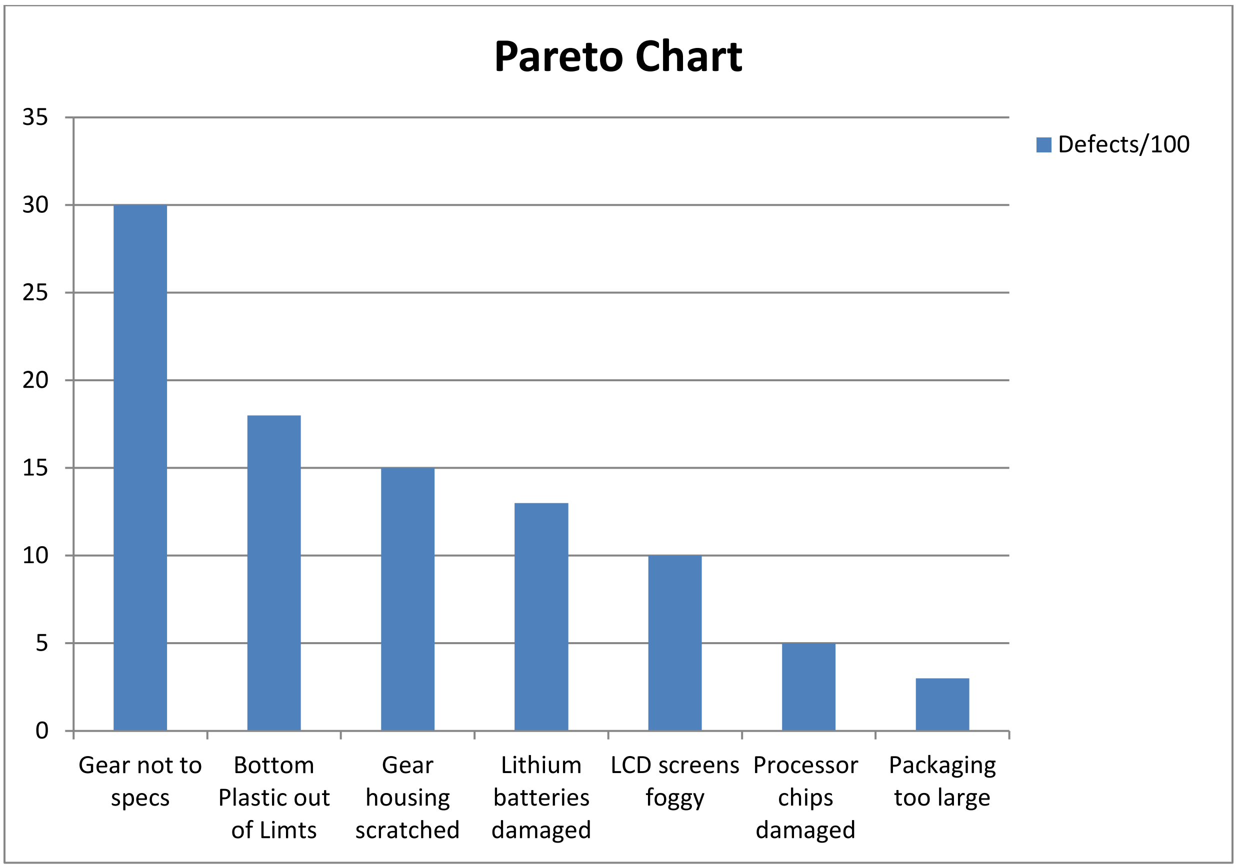


Figure 13

CAUSE-and-EFFECT DIAGRAM

The Cause-and-Effect Diagram also known as the fishbone diagram model is used to graphically depict causes that lead to an effect. The model is used in quality improvement programs to identify problems and create solutions. It is often referred to as 'Root-Cause Analysis.' The effect in this case is an operations process that is defective and needs to be analyzed and corrected. The Causes are labeled in categories to assist in assigning causes to the diagram. Figure 14 below is a typical Cause-and-Effect Diagram showing categories that need to be considered for producing the effect. The categories are; material, control, equipment, standards, procedures, and people.

CAUSE-and- EFFECT DIAGRAM

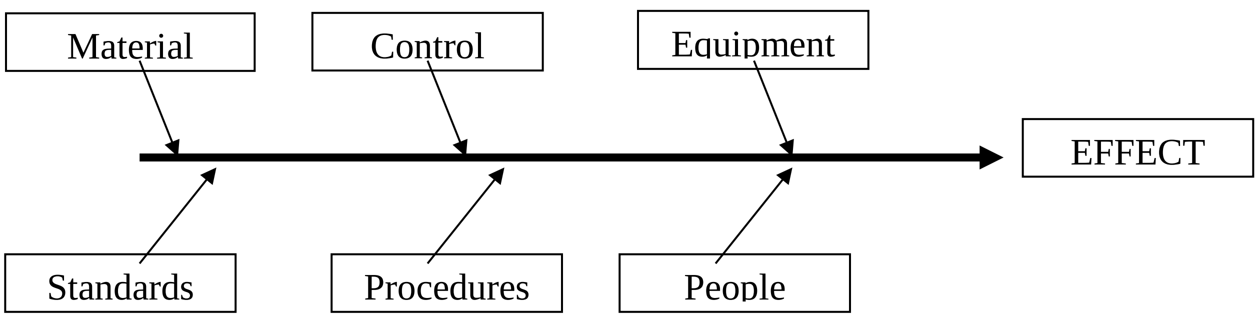


Figure 14

Each category connected with the defective gear needs to be specifically addressed and a question asked in this manner. What could have caused the gear not to be within specification?

Material question: Was the gear not to specification because the original steel casting contained gas porosity?

Control question: Was the gear not to specification because the equipment operator controls needed to be recalibrated or there was a software malfunction?

Equipment question: Was the gear not to specification because the equipment was being operated at the wrong speed or the cutting tool was worn and needed to be replaced?

Standards question: Was the gear not to specification because the wrong cutting tool was used or the cut sequence was wrong?

Procedures question: Was the gear not to specification because the procedures that were used were out of date?

People question: Was the gear not to specification because the equipment operator was not trained in the operation process or was not experienced?

The Cause-and-Effect Diagram for ARCADIA'S factory operation process that cuts steel castings into gears that are not to specification is shown in Figure 15.

Industrial and Systems Engineering

CAUSE-and- EFFECT DIAGRAM

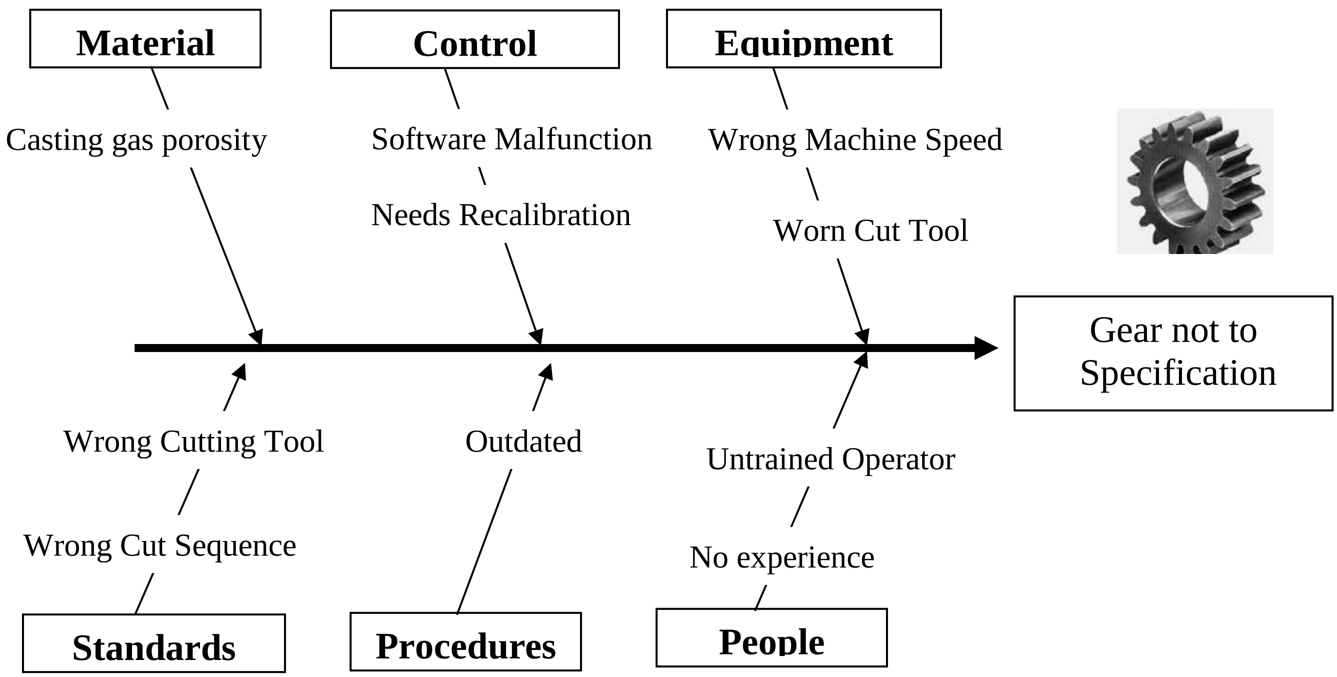


Figure 15

After reviewing each of the causes, all were dismissed except 'Casting gas porosity.' Examination was made of steel castings compared to completed gears that were not to specifications. Porosity conditions were identified by type. See Figure 16 below. Type # 2 Porosity appears to be the main cause for gears not to specification.

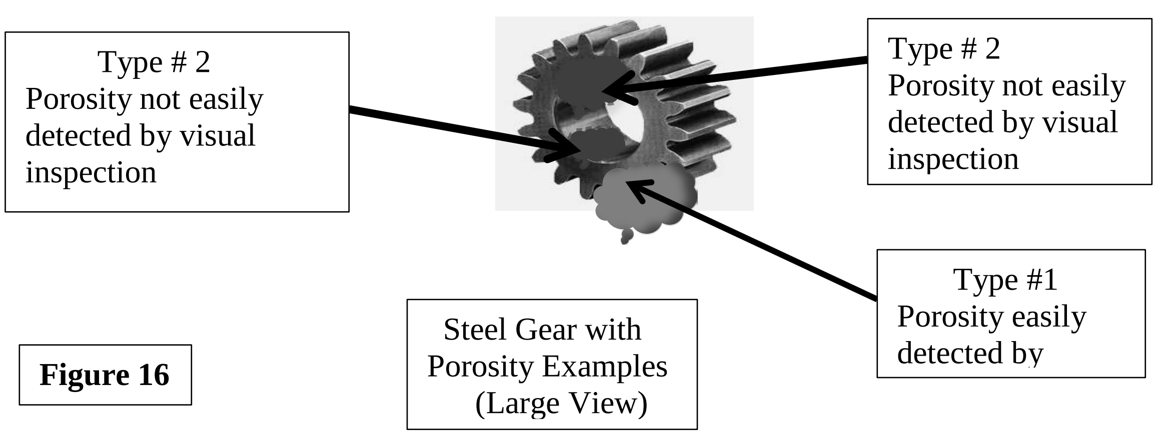


Figure 16

PROCESS FLOW CHART

A process flow chart is made of the actual operation following the operator. Each step is reviewed for process analysis by asking the following questions and deciding on action.

Questions	**Followed by**	**Action Expected**
What is the purpose?	Why?	Eliminate unnecessary activity
Where should this be done?	Why?	Combine or change place
When should this be done?	Why?	Combine or change time of sequence
Who should do this?	Why?	Combine or change operator
How should this be done	Why?	Simplify or improve method

No.	**Operator**	**Type**	**Review/Action**
1	Select steel casting from tray	Operation	The purpose of the operation is to select a steel casting from a tray to position in hobbing machine. Automation is not economically feasible**. No action**
2	Inspect steel casting for gas porosity	Inspection	The purpose of the visual inspection is to determine whether the steel casting is defective. **Action option review economic feasibility of new method/automation.**
3	Throw in recycle bin	Operation	The purpose of the operation is to return defective castings to the supplier. Customs Castings, Inc. for credit. **No further action**.
4	Clamp steel casting in hobbing machine	Operation	The purpose of the operation is to clamp the casting into position for cut. Automation is not economically feasible. **No action**
5	Check hobbing machine touch screen for ready light	Inspection	The purpose of the inspection is to determine if the casting is properly clamped in the cut position and the machine is ready to begin. **No action**
6	Touch screen for operating software update confirmation	Operation	The purpose of the operation is to confirm that the operating software is updated. If software updated. Action clamp casting **No action.**.
7	Stop hobbing machine operation and call technician	Operation	The purpose of the operation is to call the technician to check and update the software. **No further action needed.**
8	Touch screen to start hobbing machine gear cut operation	Operation	The purpose of the operation is to start the machine to cut the gear. **No action**
9	Remove completed gear from hobbing machine	Operation	The purpose of the operation is to remove the completed casting from the hobbing machine. Automation is not economically feasible. **No action**
10	Inspect completed gear with manual calibration tool	Inspection	The purpose of the manual calibration inspection is to determine whether the casting is defective. **Action option review economic feasibility of new method/ automation.**
11	Place gear not to specs in quality control tray	Operation	The purpose of the operation is to place the defective castings in a special quality control tray for analysis. **No further action**
12	Place completed gear in Pre-Assembly Tray	Operation	The purpose of the operation is to place the completed gear in the Pre-Assembly Tray to be moved into assembly area. **No action.**

Process Analysis:

Given the difficulty to identify gas porosity Type #2, the operation 2, inspection step shown below appears to be reason for the gear being defective.

2	Inspect steel casting for gas porosity	Inspection	The purpose of the visual inspection is to determine whether the steel casting is defective. **Action option review economic feasibility of new method/ automation.**

Action option review economic feasibility of new method/automation:

Option 1: Purchase Ultrasonic steel detector and have operator use detector to confirm existence of porosity. Cost = $7,000 Yuhsi Yut 2800 Ultrasonic Flaw Detector, 2 year Warrantee.

Figure 17

Option 2: Renegotiate contract with Custom Castings, Inc. to supply porosity free steel castings. Cost = $800 increase per 1000 castings.

Option 3: Make no change to operation method, absorb the defective gears and adjust cost of goods sold. Cost = $191.33 increase per 1000 castings.

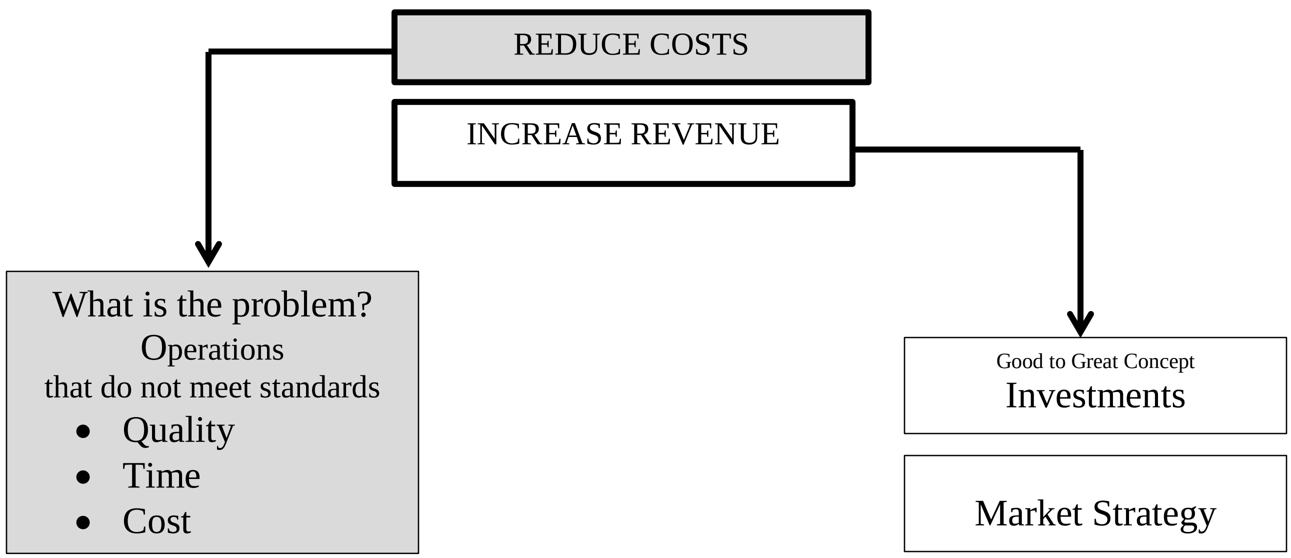
Option No.	Option	$ Cost per 1000[21]	Annual Volume Cost $ 20,000 Units
1	Purchase Yuhsi Yut 2800 Ultrasonic Flaw Detector.	$7	$0.35
2	Renegotiate Custom Castings to supply porosity free steel castings	$800	$16,000
3	Make no change to operation method. Adjust cost of goods	$191.33	$3,826

Conclusion: Purchase Yuhsi Yut 2800 Ultrasonic Flaw Detector.

[21] Appendix A

Continuous Improvement

Organizations select an operations process for continuous improvement for two reasons; 1) to reduce the cost of goods and services, 2) to increase revenue. The Operations Analysis and Design section previously discussed on page 9 will focus on cost reduction and operations improvement. Cost benefit analysis will be used to determine investments and market strategy.



REDUCE COSTS

As stated earlier, the goal of industrial engineering (IISE) is to ensure that goods and services are being produced or provided at the right quality at the right time and at the right cost. ARCADIA's organization contains a Production Controls Department staffed with a team of industrial engineers who are responsible for setting manufacturing standards and ensuring that the company's products meet the right quality at the right time and at the right cost. The duties and responsibilities of the Production Controls Department can be found on Page 7 of this document.

TOOLS FOR SELECTING OPERATIONS THAT DO NOT MEET STANDARDS

The industrial engineering team uses three fundamental tools to select existing operations process for analysis, namely the Check Sheet, Pareto Chart and the Cause-Effect-Diagram. The Check Sheet is used to record and summarize the number of defects for various products. The Pareto Chart is a graphic display provided by the quality control team and used to identify the various operations processes that have consistently not met quality, timeliness and cost standards. The Cause Effect-Diagram, also called the Fishbone Diagram, is used by the combined efforts of the industrial engineering team and the quality control team to examine the operations process that has experienced the most defects. Using the brain storming activity, the teams combine their expertise to explore various causes that might produce a defective product. The industrial engineering team next uses the Process Chart, Figure 6, page 12 that shows workflow of the operation process steps and their sequence by connecting them with arrows. The Process Chart is used to analyze the effectiveness and efficiency of an existing operation process or design a new one. Finally, the industrial engineering team uses estimating tools and the time value of money to determine cost implications of the operation process.

THE PROBLEM

ARCADIA has a product line of electric desktop paper roll calculators. The roll paper assembly uses a mechanical combination of gears to roll the paper. The original gears were made of plastic. Consumer feedback determined that the main gear was fragile resulting in the return of many desktop paper roll calculators. A decision was made to switch to more durable gear made of steel. Custom Castings, Inc. was chosen to supply steel castings. The Machine Tools & Dyes Section purchased a Hobbing (gear cutting) Machine and the industrial engineering team set standards for the production process. Recently, Check Sheet data collected from monitoring manufacturing processes by the Quality Controls Section showed that gear defects had the highest factory operating problem. This was displayed by a Pareto Chart. See page 26.

PARETO CHART

The Pareto Chart is the statistical tool that displays the various Check Sheet data and used to select the most critical operating problem that does not meet standards. The Pareto Chart on page 26 showed the number of defects for the gear to be the most critical problem and needs to be corrected.

CAUSE-and-EFFECT DIAGRAM

The Cause Effect Diagram also known as the fishbone diagram model is used to graphically depict causes that lead to an effect. The Cause-and-Effect Diagram from page 29 is used by the industrial engineering team and the quality control team to examine the gear cutting operations process. Using the brain storming activity, the teams combine their expertise to explore various causes that might produce a defective product.

PROCESS FLOW CHART

The process flow chart of the actual operation (see page 30) following the operator is reviewed by the industrial engineering team to examine each process step. A process analysis is conducted asking the following ‘why’ questions and deciding on action.

Questions	**Followed by**	**Action Expected**
What is the purpose?	Why?	Eliminate unnecessary activity
Where should this be done?	Why?	Combine or change place
When should this be done?	Why?	Combine or change time of sequence
Who should do this?	Why?	Combine or change operator
How should this be done	Why?	Simplify or improve method

The root cause was determined to be the inspection process with several options to decide on the conclusion.

Option No.	Option	$ Cost per 1000[22]	Annual Volume Cost $ 20,000 Units
1	Purchase Yuhsi Yut 2800 Ultrasonic Flaw Detector.	$7	$0.35
2	Renegotiate Custom Castings to supply porosity free steel castings	$800	$16,000
3	Make no change to operation method. Adjust cost of goods	$191.33	$3,826

CONCLUSION: Purchase Yuhsi Yut 2800 Ultrasonic Flaw Detector.

[22] Appendix A

INCREASE REVENUE

Arcadia's Chicago-metro plant has reached 100% capacity. Back orders have been increasing. The President and the executive team are considering two proposals to increase production and revenue, one by expanding the Chicago-metro plant or two, by building a new facility in Pocatello, Idaho to improve service in the western market. If the decision is to build the new facility, production would be split between it and the Chicago-metro plant. Based on Arcadia's executive business plan, a combined total of $3,000,000 loan has been made available from several banks to proceed. The consulting firm of Quality Management Group has been hired to work with Arcadia's industrial engineers to perform an engineering cost estimate and conduct a cost benefit analysis for these proposals. Present Value is used to make financial decisions seeking the larger value when comparing investments.

Installation of new production equipment at an adjacent facility next to the Chicago-metro plant is estimated to cost $2,475,000, have a one year learning curve and produce a constant annual revenue increase of $800,000. The Pocatello Plant is estimated to cost $2,550,000, have a four year learning curve and produce an annual revenue increase of $1,500,000. A five year cost benefit analysis was performed using the present value process. Present Value, also known as discounted value, is a financial calculation that measures the worth of future amounts of money in present dollars adjusted for interest and inflation. Arcadia uses a 16% discount rate.

NEW PRODUCTION EQUIPMENT
The proposed new equipment is to be manufactured based on a prototype robotic technology designed and built adjacent to the Chicago-metro plant. The technical superiority of the new type of equipment will allow for reducing reliance on suppliers and significant improvements in productivity. Transportation costs and logistics will have to be managed carefully. The financial data to support this proposal is shown below:

Initial Investment	**$2,475,000**	**Present Value Factor @ 16 percent**[23]	**-$2,475,000**
Year 1 Revenue	$700,000	.8621	$603,470
Year 2 Revenue	$800,000	.7432	$594,560
Year 3 Revenue	$800,000	.6407	$512,560
Year 4 Revenue	$800,000	.5523	$441,840
Year 5 Revenue	$800,000	.4761	$380,880
Total			**$58,310**

[23] Financial Management and Policy, Twelfth Addition, James C. Van Horne, 2002

POCATELLO PLANT
The proposed new plant is to be located at the Pocatello Business Park, Pocatello, Idaho, adjacent to the Pocatello Regional Airport. The plant will be similar to the Chicago-metro factory with some enhancements to automated material handling and advanced manufacturing technology. The new plant will be closer to the western market and transportation costs and logistics would more easily be managed. The financial data to support this proposal is shown below:

Initial Investment	**$2,550,000**	**Present Value Factor @ 16 percent[24]**	**-$2,550,000**
Year 1 Revenue	$550.000	.8621	$474,155
Year 2 Revenue	$600,000	.7432	$445,920
Year 3 Revenue	$800,000	.6407	$512,560
Year 4 Revenue	$950,000	.5523	$524,685
Year 5 Revenue	$1,500,000	.4761	$714,150
Total			**$121,470**

CONCLUSION: The present value of the Pocatello Plant is larger, $121,470 than the present value of New Production Equipment $58,310. Decision, build the Pocatello Plant.

[24] Financial Management and Policy, Twelfth Addition, James C. Van Horne, 2002

APPENDIX

APPENDIX A

Calculations: Options to change inspection of steel casting for gas porosity.

2	Inspect steel casting for gas porosity	Inspection	The purpose of the visual inspection is to determine whether the steel casting is defective. Action option review economic feasibility of new method/ automation.

Option 1: Purchase Ultrasonic steel detector and have operator use detector to confirm existence if porosity. No change in inspection time. Material Cost = $7,000 Yuhsi Yut 2800 Ultrasonic Flaw Detector, 2 year Warrantee.
Cost increase per 1000 = $7

Option 2: Renegotiate contract with Custom Castings, Inc. to supply porosity free steel castings. Cost = $800 increase per 1000 castings.

Original Cost of steel casting $2.25 x 1000 = $2,250
New Cost of porosity free casting $3.05 x 1000 = $3,050
Cost increase per 1000 = $ 3,050 - $ 2,250 = $ 800

Option 3: Make no change to operation method absorb the defective gears and adjust cost of goods sold. Cost = $191.33 increase per 1000 castings.

Material = 4 defects per 48 observations = 83 defects per 1000
Cost of material = 83 x $2.25 = $ 187.50

Labor = Normal time of .32 seconds
Labor = Standard time of .368 seconds per cycle
Labor = 368 seconds per 1000 units or 6.13 minutes
Labor = 6.13/60 minutes per hour operator time @ $37.50 per hour = $3.83

APPENDIX B

ARCADIA production volume and financial data for Chicago – metro facility

- **Type**
- **Annual Volume**
- **Sales Price**
- **Revenue**
- **Cost of Goods Sold**
- **Profit**

Electronic Handheld Calculators

Type	Volume	Price	Revenue	Cost	Profit[25]
Accounting	150,000	$40	$6,150,000	$5,737,950	$2,324,700
Engineering	100,000	$40	$4,100,000	$3,825,300	$1,231,025
Scientific	75,000	$40	$3,075,000	$2,868,975	$206,025
Total	325,000		$13,325,000	$12,432,225	$3,761,750

Electronic Desk Top Calculators without Paper

Type	Volume	Price	Revenue	Cost	Profit[26]
Accounting	30,000	$45	$1,380,000	$1,287,540	$521,640
Engineering	20,000	$45	$920,000	$858,360	$61,640
Scientific	50,000	$45	$2,300,000	$2,145,900	$154,100
Total	325,000		$4,600,000	$4,291,800	$737,380

Electronic Desk Top Calculators with Paper Roll

Type	Volume	Price	Revenue	Cost	Profit[27]
Accounting	10,000	$70	$710,000	$648,230	$61,770
Engineering	10,000	$70	$710,000	$648,230	$$61,770
Scientific	20,000	$70	$1,420,000	$1,296,460	$123,540
Total	40,000		$2,840,000	$2,592,920	$247,080

[25] Profit Margin 0.067%
[26] Profit Margin 0.067%
[27] Profit Margin 0.087%

APPENDIX C

ZHANGJIAGANG BEIER MACHINERY COMPANY, LTD

Extruding Machine
SJZ65/132 PVC CONICAL TWIN SCREW EXTRUDER

1. Screw diameter 2.5/5 inch
2. Motor power (kW):22
3. Extruder Machine Capacity (lbs./h):550-770
4. PLC Control Siemens, s7-1200
5. Application: PVC pipe, profile, sheets, tile, etc.
6. Accepting customization (misc. small parts)

The BEIER machine is an example of a machine that uses plastic raw material, polyethylene and polycarbonate granules to extrude plastic sheets, tiles and various small plastic parts for calculator assemblies.

APPENDIX D

SUTHERLAND AUTO SAMPLER PRESS

The Sutherland press is an example of a press that uses plastic sheets to form outer plastic cases for calculators, packing forms, small nested parts and various inserts for shipping boxes.

Sutherland I-Press
9” & 10” HD color Touchscreens
Allen Bradley & Omron Platforms
Real time Status Readouts
200 + Job Memory
12 Programmable cams
16 Die monitors
130 separate function monitors

APPENDIX E

Precision PCB Srvices, Inc.

The NXR-1525 Xray System is used for PCB X-ray inspection. It is a high resolution X-ray system that can show inner layer traces of the Circuit Board.

The NXR-1525 Xray System is an example of an automated machine that inspects printed circuit boards (PCB) that are used for electronic desktop calculators.

APPENDIX F

Production Control Software

Computer software technology currently provides time and cost saving benefits to control inventory and production. And, there are many organizations that provide software support. An example of manufacturing software products is "Integrated Quality Management Software" (IQMS®). Among their products are manufacturing software, quality management software, and warehouse management software.

QMS' Manufacturing ERP Solves Your Manufacturing Challenges

The all-encompassing Enterprise IQ ERP & MES software solution is designed to solve manufacturing challenges and help you:

- Increase efficiency
- Eliminate unnecessary downtime
- Enhance manufacturing production and performance
- Improve supply chain visibility

https://www.iqms.com