COLLABORATIVE MANUFACTURING PLATFORM FOR INDUSTRY 4.0

M.Tech. Thesis

by

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DISCIPLINE OF MECHANICAL ENGINEERING

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A THESIS

Submitted in partial fulfilment of the requirements for the award of the degree
of
Master of Technology

by

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DISCIPLINE OF MECHANICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY INDORE

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **COLLABORATIVE MANUFACTURING PLATFORM FOR INDUSTRY 4.0** in the partial fulfilment of the requirements for the award of the degree of **MASTER OF TECHNOLOGY** and submitted in the **DISCIPLINE OF MECHANICAL ENGINEERING Indian Institute of Technology Indore** is an authentic record of my own work carried out during the time from May 2019to June 2020 under the supervision of **Dr. Bhupesh Kumar Lad**, Associate Professor, Discipline of Mechanical Engineering, Indian Institute of Technology Indore.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other institute.

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This is to certify that the above statement made by the candidate is correct to the best of my/our knowledge.

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Akshay D. Mate has successfully given his M.Tech. Oral Examination held on 25/06/2020

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Signature of PSPC Member
Date: 30/06/2020

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Date: 30/06/2020

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Akshay D. Mate
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Dedicated

To

My family

And

My Guide

ABSTRACT

Information and communication technology are undergoing on the rapid development phase,and many innovative technologies, such as the Internet of Things (IoT),artificial intelligence (AI), cloud computing and big datahave appeared. Today, advancements in technology are taking place exponentially. The Internet of Things (IoT) need rises; the application of computer technology is becoming ubiquitous. These technologies are filling the manufacturing industry and enable the integration of virtual and physical worlds through cyber-physical systems (CPS), which lead towards the fourth stage of the industrial revolution (i.e., Industry 4.0). Considering the area of Manufacturing, machines and industries are becoming smarter. However, considering the bigger picture, as the society is now thriving for mass-customization, in this work, we propose an operation management system that will enable industries to achieve the goal of "mass-production with mass-customization" which is the next challenge for the industry. The project is on Industry 4.0 the application of Cyber-Physical Systems (CPS) and IndustrialInternet of Things(IoT) and in the manufacturing industry to create a platform capable of remote monitoring, intelligent production planning, and autonomous real-time decision making. It intelligently works towards the goal of mass-production with mass-customization and make data-centric decisions using cyber-physical transformations and the Internet of Things.

Thus, we devise a platform, termed as Collaborative Manufacturing Platform (CMP), which will make this possible. It will interconnect and enable interaction between the pillars of manufacturing viz. suppliers, co-industries, customers, and the industry-leading to enhanced profits and efficient real-time decision-making. Python programming based simulation has been developed in this work. Typical characteristics of the program include capacity calculation, availability of industry, failure of the machine, defective product,

customer probability, cost analysis, real-time scheduling, etc. Cost analysis, according to a smart selection of suppliers and co-industry, every time is done with the change in demand. The intelligent selection of suppliers and neighbouring industries through the algorithm ensures the best possible amalgamation of the lowest cost, best quality, and availability. The algorithm developed in this work is capable of all the decision-making ability and smart selection of suppliers and co-industry. Parameter's weightage can be managed according to the industry requirement.

Using the Collaborative Manufacturing Platform (CMP) may lead to increased profit in the existing benefit. Overall increase in the number of customers and thus increase in profit for both the customers and industry.

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ABBREVIATIONS

CPS – Cyber-Physical System

IoT – Internet of Things

RTLS - Real-Time Locating Systems

RFID - Radio Frequency Identification

CMP – Collaborative Manufacturing Platform

MPA - Mass Production Approach

ACA - Available Capacity Approach

CHAPTER 1. INTRODUCTION

1.1. Industry 4.0

Nowadays, Industrial production planning is driven by competition around the world and the need forfastconvergence of production as per the changing market scenario.These requirementscan be encounter only by absoluteadvances in current production technology. Advancements in technology are taking place exponentially. Industry 4.0 conceptwas introduced by the German government. The modification of an industrial manufacturing system through digitalization and the use of the ability of new technologies are the goals. It is a process based on the fusion of themanufacturingprocesses and business, and alsothe integration of all factors in the company's value chain(customers, suppliers,and other industries) [1]. The 'Fourth Industrial Revolution' (Industry 4.0)which is defined as a new level of organization and it control the entire value chain of the product life cycle, and it is adapt towards increasingly individualized customer needs [2]. The central objective of Industry 4.0 is satisfiedindividual customer requirement which affectsareas likeresearch and development, order management, manufacturing commissioning, delivery up to theuse and recycle and reuse of products[3]. Industry 4.0 model promotes the link of physical items such as sensors, devices, and enterprise assets, bothto each other and to the internet [4].

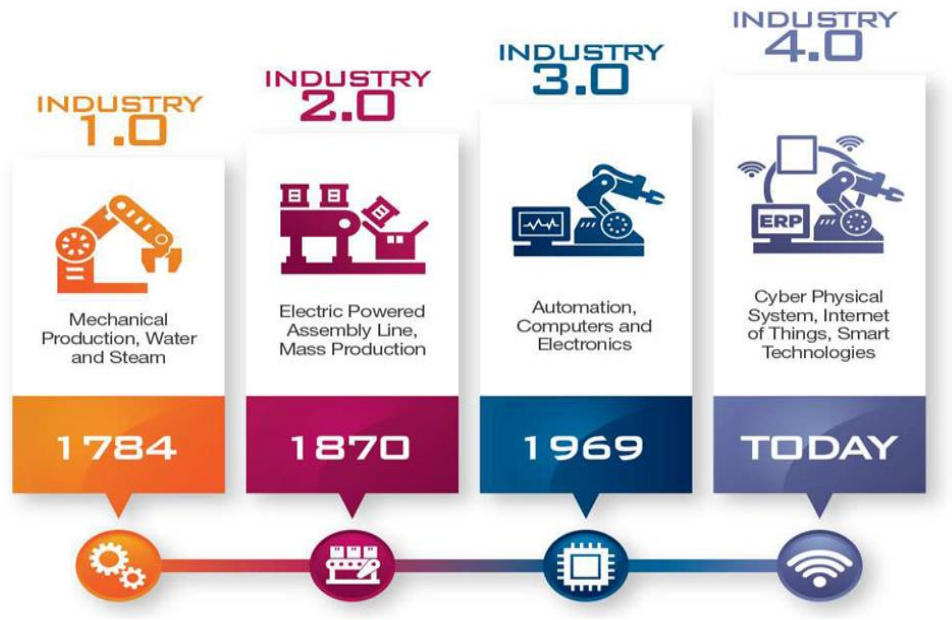


Fig.1.Four Industrial Revolution [5]

1.2. The need of Industry 4.0

The necessity of industry 4.0 is to modify the methodical machines to the smart device to improve their overall execution and maintenance management with the local interaction [6]. Industry 4.0 target at the establishment of an open, intelligent manufacturing platform for industrial-networked information applications [7]. Real-time data analysis, tracking the condition of the product as well as to carry the instructions to control manufacturing processes are the fundamental needs of Industry 4.0.Industry 4.0 is comprisedof anintegration of new technical components and primary principles to create and configuration the concept to get vertical and horizontal integration of value networks [8].

1.3. Components of Industry 4.0

The core of this Industry 4.0 is the internet of things (IoT), which enablesthe connection of machines, systems,products, and people.The main componentsof Industry 4.0 are:

Fig.1. Industry 4.0 Technologies [9]

- Identification: The identification of the processing goods is the first step.
- Locating: Identification used to be linked with locating or recording the place, to determine it, Real-Time Locating Systems (RTLS) are used.
- Cyber-Physical System (CPS): In Manufacturing, CPS is the physical system accompanied by computed-based processes, using the conceptualization of omnipresent computing. It incorporatessensors and actuators by using so the data can collect and send.
- Internet of things (IoT): By using IoT, the industry can oversee their every product in real-time and management of their raw material and logistics architecture can be done. The CPS enables communication with other CPS, and between users and IoT, it's part of it.

- Big Data and Data Mining: In current years, the amount and types of collected data have increased because of the advancements in sensor technology and the products containing computer function.
- Business Service: Vendors to offer their services via the internet by using this. It comprises of business models,participants, infrastructure for services, and the services themselves [10].

Using CPS building blocks and the Internet of Things (IoT) and connecting them help to execute the Industry 4.0 system. These blocks are immersed systems with decentralized control and advanced connectivitythat are gathering and exchanging real-time information to identify,locating, tracking, observing, and optimizing the manufacturing processes.

1.4. Cyber-Physical Systems (CPS)

The basic definition ofCyber-physical systems is the integration of physical systems,computers, and networks. The utilization of cyber-physical systems through technology by using the combination of wireless control systems, production-based sensors,wireless systems, and machine learning. By combining physical systems andcyber systems together,it's possible to communicate with the people. Replicated systems are a union of logic and sensor unit, and physical systems summation of actuator units. By the ability to interact and expand capabilities of the physical world using computing ability, communication technologies, and control mechanisms, cyber-physical systems allow feedback loops, improvisingthe industrial production processes and optimum the people support in their decision – making processes [11].

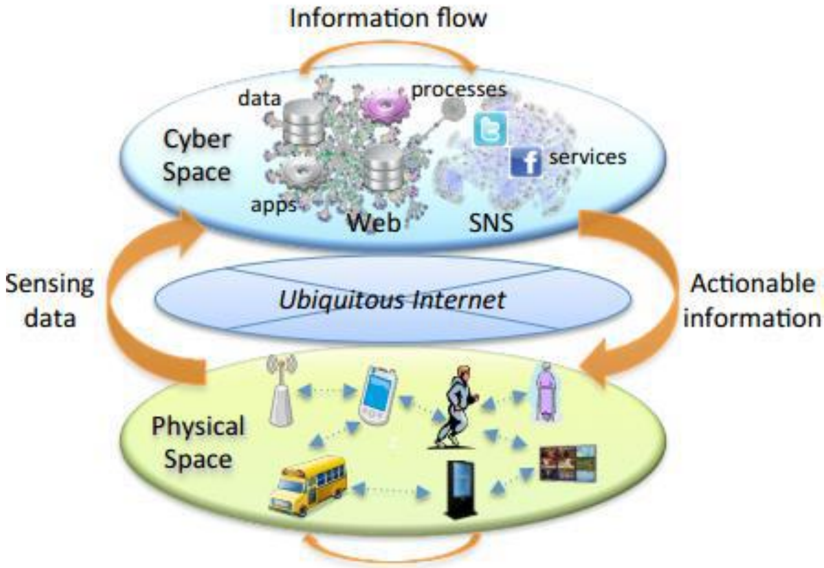


Fig.3. The flow of information between the Physical and Cyberworld [12]

By using similar sensor technology, CPScan receive direct physical data and convert them into digitalize signals. They can access and share the available data and information, and that links it to digital networks, thereby making an Internet of things.CPS will enable communication betweenmachines, humans, andproducts. The components of a CPS can acquire and process data and can self – control specific work and make interaction with humans through the interfaces, figure 1.3.[13].

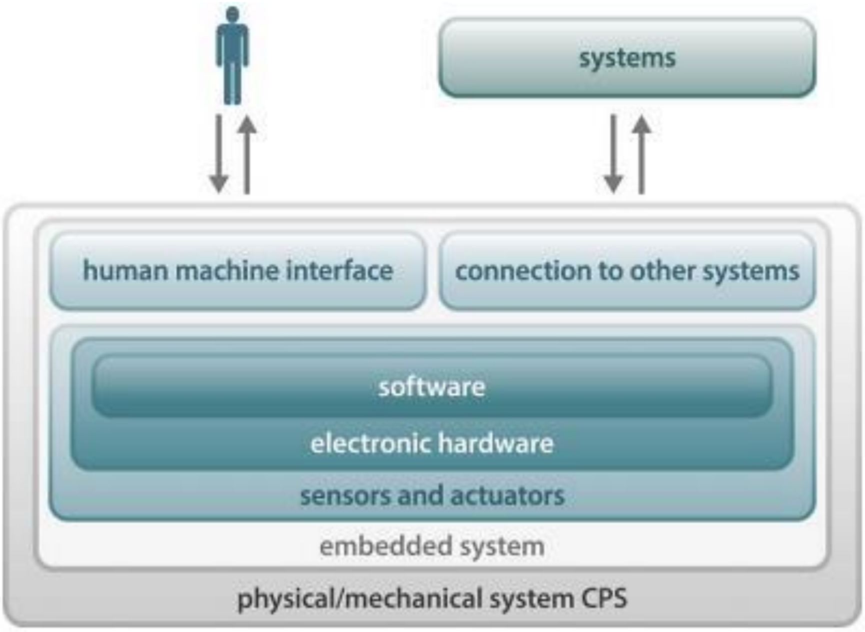


Fig.4. Interaction betweenMachines and Humansin Cyber-Physical [14]

1.5. Internet of Things (IoT)

The Internet of Things (IoT) is briskly acquiringground in the world of wireless telecommunications. It includesa variety of objects – such assensors,mobile phones, Radio – Frequency Identification (RFID) tags, actuators, etc., through whichthey caninterconnect with their neighbours and cooperate and each other, to reach simplegoals [15]. IoT is active participants in information, industries,business, and social processes. Where they are allowed to takecommunicate,and interactionwith themselvesand with the surroundings and by interchange data and information collected about the surroundings while reacting independently to the real-world functionsand modifyingit by running processes that activate actions, and creating a facility with or without direct human interference.

Roughly speaking, the Internet of Things means a worldwide network of interconnected and constant addressed things that communicate via quality protocols. In such systems, a large number of tool present an individual address for data exchange, which is a severe problem[16].

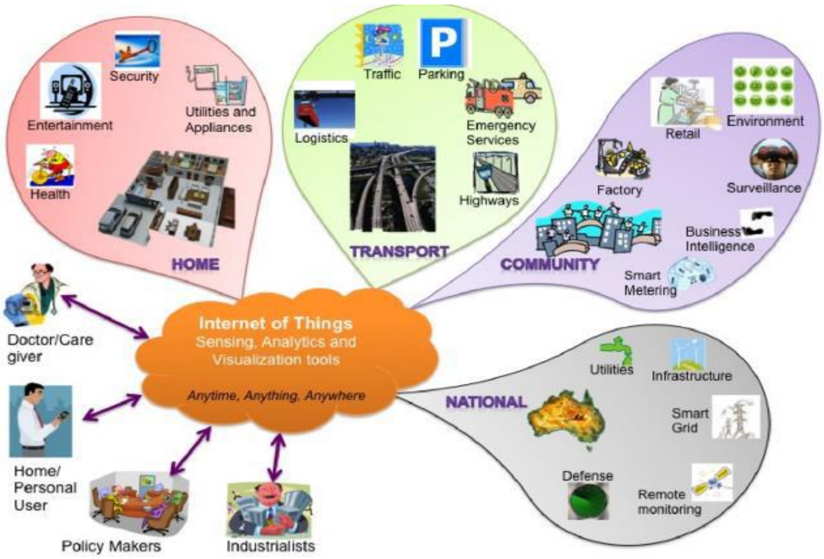


Fig.5. Internet of Things [17]

To visualize the consumption of the IoT in the manufacturing process, the graphic below from Microsoft offers an excellent summary.

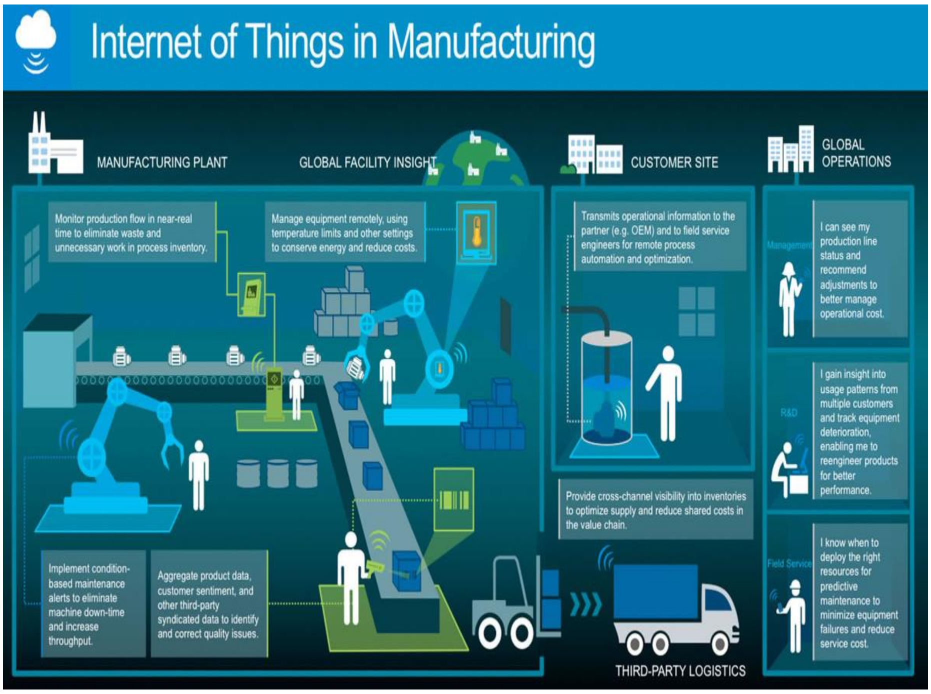


Fig.6. Internet of Things (IoT)in Manufacturing

Benefits offer:

- Production flow supervising: Eliminate waste,optimize flow, and avoid unneeded work in process inventory.

- Situationbased maintenance: Minimize interference,upgrade machine availability, and increase production.
- The consumption of diverse types of data (product, customer sentiment, and others), as operatorsof quality observing and augmentation in the function of outputs and this collected data.

IoT is modifying the way coordination in different industries are doing business, including the manufacturing industries. Until now, technology has been used primarily for managing the business and managing manufacturing operations, for computerization processes and for gatheringthe data related to assembly jobs. IoT goes well yonder this to the next level for the gathering the data.

1.6. The organisation of the Thesis

Chapter 2includes the detailed literature review on the past work reported in the relevant field of Industry 4.0, challenges associated with, different technologies which are involved under Industry 4.0, the identified research gaps, the research objectives defined to bridge the identified research gaps and research methodology used in the present work.

Chapter 3 includes the Collaborative Manufacturing Platform (CPM) Model, different approaches to this model. Detail working of the CMP. Pillars of CPM and characteristics of all the components.

Chapter4 consist of results got after running the different models and how the different parameter effect on the results.

Chapter 5 highlights the conclusions of the present work and marks the scope for future work based on the limitations of the present work.

CHAPTER 2. LITERATURE REVIEW AND RESEARCH OBJECTIVES

2.1. Background

When we think of the revolution about the industry, many object come in mind. In the eighteenth century, some people of the changes in production brought about by the use of machinery. Today many of this reportcentres on Industry 4.0, so it is essential to know in the breach from the first industrial revolution to the current set of advances Technology (Industry 1.0 to Industry 4.0).

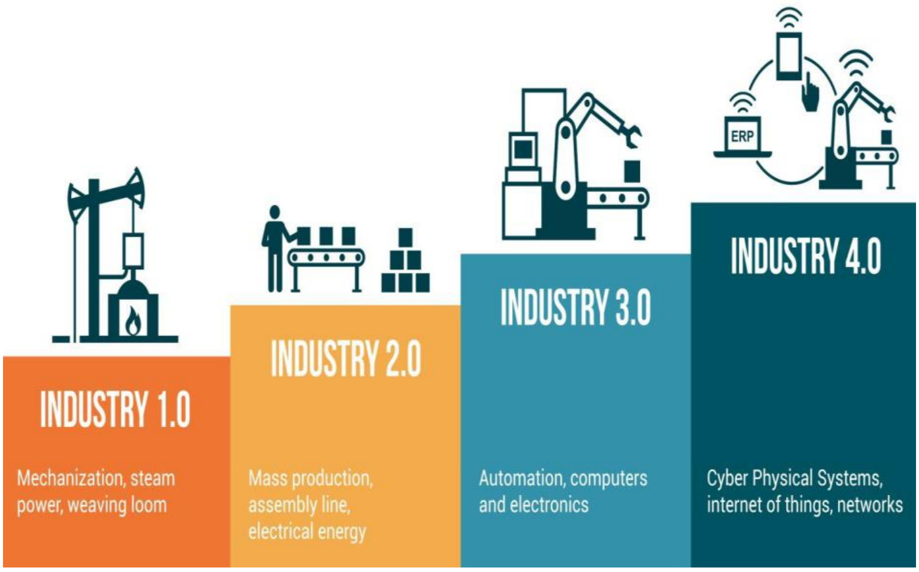


Fig.7.The chronological industrial revolutions that shaped the Manufacturing [9].

2.1.1. The First Industrial Revolution (Industry 1.0)

Into the world of machines, the first revolution drives economies around the globe out of farming and handicrafts. Handmade goods and farming still form a considerableportion of today's economy; they are not pretentious by the use of machinery. The first industrial revolution begins in the year 1760 with the conception of the steam engine. The conversion from feudal society and farming to the new production process is allowed due to the steam engine. This transition included the trains were the primaryway of transportation and employ of coal as the leading energy. Steel and textile industries were the ruling industries in terms of employment, capital invested, and value of output [18].

The improvement introduced in the manufacturing industry :

- The innovation of new machines, like spinning jenny
- Transportation and communication upgrade
- Coal as the new energy source
- Steel as a new raw material
- Labour and worker specialization division [19]

2.1.2. The Second Industrial Revolution (Industry 2.0)

In 1900, with the invention of the internal combustion engine,the second industrial revolution began. The era of electricity to power mass production and speedy industrialization using oil began. At this time, manufacturing industries began experimenting with more synthetic materials and machines. Computers were invented, and automatic working came into existence, and plastics attach with the production line. World War 1 also helps in the manufacturing revolution. Two key feature was observed during industry 2.0 are mass production and electricity used [19]. The development of several management programs occurs, which made it feasible to raise the efficiency and effectiveness of manufacturing service. Worker efficiency and workplace methods, such approaches were introduced by American mechanical engineer Frederick Taylor. Just-in-time and lean manufacturing conceptwere further purified,so; manufacturing industries could upgrade their productivity, quality, and return [9].

2.1.3. The Third Industrial Revolution (Industry 3.0)

Electronic devices and information technology systems were the key features of industry 3.0. The formulation and Manufacturing of electronic devices like a transistor and amalgamated circuit chips made it workable to more fully automated independent machines than the second industrial revolution to add or replace the operators.Under Industry 2.0, making things intricate screwing or welding lots of parts together were theold ways[9].The rapid change has occurred from analogue to more digital systems in manufacturing plants. Many of the menial thingswhich are previously done by humans were taken by debut automation software at this time. Thefirst big scare that mass human unemployment lead by machines use [19].

2.1.4. The Fourth Industrial Revolution (Industry 4.0)

In the 21st century, the connection of the IoT with the manufacturing techniques as the concept of Industry 4.0and smart Manufacturing to allow the systems to share and analyze the data. Use this to guide decision making quicksteps.Artificial intelligence (AI), additive manufacturing,robotics, and other cognitive technologies, augmented reality, and advanced materials, are incorporated in it. A primary driver ofIndustry 4.0 is the evolution of new technology. Manufacturing execution systems, shop floor control, and product life cycle management, such programs first developed during the 20th century,longsighted concepts that deficientin the technology needed to make their complete execution possible. By the help of Industry 4.0, these programs reach their full capacity [9].

Industry 4.0 involves additive Manufacturing,three dimensional (3D) printing and computer-generated product design, which can create solids object by building up layers by layers of materials.CPSis the critical feature of this revolution. IoT provided anew level of interconnectivity [19].

Sr. No	Span	SwitchSpan	Power Resource	Primary Technical Achievement	Main Developed Industries	Transport Medium
1	1760-1900	1860-1900	Coal	Steam Engine	Textile, Steel	Trains
2	1900-1960	1940-1960	Electricity, Oil	Internal Combustion Engine	Machine Building, Metallurgy, auto,	Trains, Cars
3	1960-2000	1980-2000	Natural Gas, Nuclear Energy	Robots, Computers	Chemical, Auto	Cars, Plane
4	2000-	2000-2010	Green Energies	Internet, Genetic Engineering, 3D Printer	High Tech Industries	Ultra-Fast Trains, Electric Cars,

Table 1. The industrial revolutions [18].

With the primaryaim of satisfying customer requirements, Industry 4.0, incorporate the digitization of horizontal and vertical value chains, and it will reorganize the product and its service portfolio of industries. The current manufacturing industriesare more global, generatinginterconnection between the physical system and the cyber system. The enterprises need to manufacturemass quantities using less raw materials and energy.The CPS and IoT allow asset efficiencyand higher production rate and thus creates the conditions for continuous and efficient production with mass customization. An average increase in efficiency of 3.3% per year across all industry areas anticipated by companies surveys due to the digitization of value chains. IoT will have a notable effect on existing business methods, and it will develop new digital business methods. Increasing customer satisfaction through a different span of value solutions and the relation (connectivity) with customers and associateare the focal point of this trend [20].

Industry 4.0 addresses research and development actions incritical areas to support its acquisition in the industry:

- Standardization:Collaborative association of organizations in value networks needed a set of similar standards.
- Compound systems management:The excessive difficulty of systems and products neededa suitable method for their control.
- Extensive broadband framework for Industry:IoT requires a dependable and quick communicationnetwork framework.
- Protection and Security:Machine-humaninterconnection, production systems must not hurt people and the environment. The data and information needed access and approval.
- Work operation and design:Along with machinesand processes of work, the environment will also change, giving the employee responsibility.
- Training and Professional Development: The worker requiresto be qualified viaadequatetraining and life-longeducation.
- Managing structure:Law-making has to take into account innovations, mainly for privacy and accountability regulations.
- Resource effectiveness:Raw material and energy consumptions should be lowered by upgrade production rate and resource effectiveness [21].

2.2. Principles of Industry 4.0

- **Interoperability**

  Interoperability means, to exchange machines and equipment that perform the same function, even from different manufacturers. This gives rise to multiple networks in a trusted environment for equipment to intercommunicate, enabling an awareness that is required for the development of Industry 4.0 intelligent functions [22].

- **Decentralization**

  Decentralization, as understood in Industry 4.0., is the increased ability of local companies, operations personal, as well as machines to make decisions. Instead of using central computers, capacitating and allowing local operators to respond to changes and readapt themselves grants more flexibility and facilitates the use of specialized knowledge. This fits with a decomposition of the classical hierarchy of production and a shift towards decentralized self-organization [23]. The growing demand for individual products makes it increasingly difficult to control systems centrally. Embedded computers allow the CPS to make necessary decisions on their own [24].

- **Virtualization**

  Virtualization means that through the usage of monitoring and machine-to-machine communication, a virtual twin can be abstracted. The sensor data are linked to virtual plant models and simulation models. In this way, a virtual copy of the physical world is created. In case of failure, a human being can be notified. Also, all necessary information, such as the next work steps or safety provisions, are provided [25]. Cyber-Physical Systems offer to close the gap between information sharing and production of sense by promoting decentralized communication, while two features of Industry 4.0 are fundamental: At first, the activeness of the sensors will make it possible to obtain information about a new level of granularity with the least likely delay. Second, the real-time data-based simulation will allow the anticipation of the effect of local optimization in the general context, allowing a better sense-making and using decentralized control circuits [26].

- **Real-Time Capability**

The data must be collected and analyzed in real-time to perform the organizational tasks, but the Industry 4.0 notion of real-time capability goes a step further. It includes plants that can react to the failure of one machine and forward products to another machine as well as a throughout linkage between the end consumer, via social network or direct selling points, that allows for a faster response to changes in demand [27]. This use of real-time information and robotic systems is set to disrupt the modes of production, and the way Manufacturing is currently organized. This is something that will affect all types of functions, from engineers to maintenance operators, and will also change the physical locations of the plants [28].

- **Modularity**

  This principle involves modular systems that can adapt flexibly to changing requirements by replacing or expanding individual modules, which makes adding or removing production modules in a much easier way. These modular systems can, therefore, easily be adjusted in the event of seasonal fluctuations or changes in the product's production needs, such as in the case of incorporating new technologies [27]. Also, many manufacturing processes, such as product design, production planning, production and production engineering, and services, will be simulated as modular and then will be closely connected end-to-end and interchangeably [29].

- **Service Orientation**

  Within this principle, business, human, and CPS services are available through the internet of services and can be used by other participants, facilitating the creation of product-service systems. They can be offered internally and across company boundaries [27]. Service orientation and transformation enable organizations to be agile and flexible, and it responds to market changes much more quickly. Enterprise I.T. is becoming more resilient to partner with the I.T. networks of its value chain partners to co-create value for consumers. Organizations can collect and process unprecedented amounts of data with massive unstructured data solutions [30].

2.3. Industry 4.0 happen by

1. For local decentralized information processing, the connectivityprovided by networked systems.
2. High-performance sensors, actuators, etc.
3. Auto-ID for personalized product production creates individual identification and connects to the virtual world.
4. Allowing for the dynamic,broad distribution of functions is an internal part of the system which integration by using Intelligent field devices.
5. Mobile Device Management: Without any specialized training, man-machine interfaces for the inherent operation of compound systems [31].

2.4. Literature Review

This section presents the detailed literature review on the past work reported in the relevant field of Industry 4.0, challenges associated with, different technologies which are involved under Industry 4.0, the identified research gaps, the research objectives defined to bridge the identified research gaps and research methodology used in the present work.

2.4.1. Industry 4.0

Mamad, review the overview of Industry 4.0 meaning, challenges occur during implementation and benefits after implementing the Industry 4.0. He also has given a thorough definition of Industry 4.0 and explains the research methodology behind it. Further, he presents the review for the current and future concept of Industry 4.0 and the connection of humans, objects and systems that forms dynamic, real-time optimized and self-organizing. By implementing Industry 4.0 productivity, flexibility, and quality standards can be increased [10].

Jeevitha et al. presented and facilitate an understanding of Industry 4.0 concepts and its drivers, goals, enablers, and limitations. The core of Industry 4.0, the Internet of Things (IoT), which the connection among machines, people, and things. They reported basis for Industry 4.0 was the availability of all relevant information at real-time. The execution of the Industrial Internet is a multi-year transformation process. Alsocommented on digital business models which will expand the existing product and service methods to ensure future growth in demand and sales [9].

Min et al.discussed the significant features of Industry 4.0, and the opportunities, and the challenges of the fourth industrial revolution. They have examined the benefits of Industry 4.0, like a large number of people worldwide are likely to use socialmedia platforms to connect, learn, and share information. Also,a variety of innovative manufacturer and competitors industry will have easy access to digital platforms of marketing, sales, and logistics,so improving the quality and price of products and services offer. They also saidcustomers would be more involved in the production planning process and the distribution process. The primary effects of this revolution on the business environment that it move toward collaborative innovation, and innovations in organizational forms [18].

Dorleta et al.conducted a review to expand our knowledge about how Industry 4.0 will affects the business model and identify a suitable business model innovation. From the results, they recognise the set of features, issues and requirements for Industry 4.0. They also suggested three different approachesto make firms getting closer to the industry 4.0 phenomenon such asnetworked ecosystems, service orientationand customer orientation.They give even the suggestion of Business Model components for Industry 4.0. [34].

Judit et al. done research onwhat critical issues industry facedto adapt to Industry 4.0. They had sent an onlinequestionnaire to the manufacturing industry and logistical service companies to investigate the Internet of Things tools they were usingand the problems they were facing. They found that sharing of real-timedata across the industry andthe availability of proper analytical methodshave a remarkable impact on the entire industry [39].

2.4.2. Collaboration by using Industry 4.0.

Nubia et al.describe the primary forms of collaboration of Industry 4.0 concerning feasible. They discuss the advantages given by industry 4.0, like improved productlife cycles and efficientManufacturing, by incorporating the principles of industry such as virtualization and decentralization, with cyber-physical systemsguide to more adaptability to natural resources availability. Theyhadpresent work which involves the primary inventiveness ofindustry 4.0, expressed in its principles, for the formation of an industrial model with high capacity to create,maintain and fully use the energetically sustainable system, processes, techniques and strategies [35].

Luis M. et al. from the analysis they studied the collaboration problems are at the heart of most challenges of Industry 4.0. They also reported collaboration needs to be made at all dimensions of Industry 4.0 vision and needs along its six dimensions –horizontal integration, vertical integration, acceleration of Manufacturing, through-engineering, digitalization, and new business models – which helps to recognize a large number of collaboration-related problems [36].

2.4.3. Smart Factory

Klaus-Dieter et al.given an overview of Industrie 4.0 and SmartManufacturing programs. Discussed and analyze the applicationpotential of CPS. It involves the product design,production, maintenance,recycling and logistics, andidentify the current andfuture research problems related to it—also, non-technical perspective like the economic side with the new businessstrategies and new models.Smart Manufacturing is heavily focused on data, supply network, integration of information and technology, involving human in the loop [21].

Shiyong et al. discussed on thevertical integration to implement flexible and smart factory. They had proposeda framework that consists of industrial wireless networks, cloud, and fixed or mobile terminals andintelligent things such asproducts, machines, and conveyors. They conclude the smart factory of Industry 4.0 is feasible by widely applying theexisting technologies while actively coping with the technical problems.They concluded that the smart factory assists to execute the continualproduction mode to tackle the global market challengesand which can lead to novel business modes [20].

Dragan et al. show the ways of Industry 4.0 future developmentand the future concepts of the smart factory. The applicationbased on CPS and the internet,which leads to notable improvements, likean increase in automation and minimizing the periodbetween the new productdevelopment and its launch. They define the advantage of the smart factory which makes a solution, due to which thesystem's automated procedures, need-based installation, an uncomplicated setup which can help theindustries in theManufacturing to optimize their production processesand significantly increasedthe efficiency [31].

Pai et al.had examined smartmanufacturing systems for Industry 4.0. They have presented the conceptualframework of smart manufacturing systems for Industry4.0. and also a demonstrative plot thatobtains the design, machining, control,monitoring, and scheduling, which are to be smart. Revision of key technologies and their applications toIndustry 4.0 done by them. The challengesand future view are identified and discussed [37].

Elvis, done review on the smart factory for industry 4.0 and discussed the exposure ofthe Internet and related technologies which had made significant progress in all human activities. It isan irresistible combination in manufacturing systems, which will affect the rise in thecomplexity of theexisting manufacturing systems, as well as new systems, such as CPS. He also discussed the current,and future development is characterized by keen and quick scientific and technological changes, whichresult with reindustrialization existing industries andthe revitalization of a broad range of human activities [38].

2.5. Gaps

In such a competitive environment, to achieve their goals, manufacturing companies are exploring the new technology to attract more customers and maintain in the market.Some of the most common challenges that manufacturing industries have to deal with are listed below:

- **Integration Need:**

  There is a need for integration between Equipment, People, and Processes.There is a lag in communication about fluctuations in demand and supply from customers and vendors (Co-Industry), respectively. Information collecting of processes, parts, peoples, etc., on the shop-floor, and the databases created and thus, are generally discreetly located and not analyzed in real-time to provide reflections on dynamic performance improvement.
- **Unavailability of data:**

  The availability of data of sufficient quantity and quality isessential to make data-centricdecisions. This data, currently, more than being unrecorded,remains unidentified in many cases.
- **Handling of data Unstandardly:**

The variability in datasourcesgeneration, the device of data-recording, and the facility of dataprocessing cause a high amount of heterogeneity in the data, severelyrestricting integrated planning of operations.

- **Real-time decision-making system:**

  The absence of a real-time decision-making system makes it challenging to tackle the fluctuating demand.

- **Existing planning systems rigidity:**

  Though systems for operationsplanning exist in most industries, these remain greatly under-exploited, given the inability to accommodate the frequent changesoccurring in the processes and the high amount of time, cost, andtraining spent into it.

- **Operations Planning based on experience:**

  Conventional operations planning methods arecurrently centralized, whichautomatically induce computational limits.This leadsto limitingthe spread of process attributed to local industrial entities only, suchas a machine or an assembly line with lesser parametric consideration.

2.6. Motivation

Industry 4.0 is promising the future of the manufacturing industry with the use of different technologies, which makes manufacturing industries one step close toward Smart manufacturing. More real-time data can be gathered by connecting the assets, enabling better decision making. With the advancement of internet technology, e-manufacturing, e-commerce, e-procurement, etc. have already become a reality. This gives motivation to a more extended concept called "Smart Manufacturing' where people will want to browse, customize, order, and run the factories to get their products made by themselves. Industry 4.0 is the sole enabler for this transformation from 'Mass-production' to 'Mass Customisation.' However, more importantly, Industry 4.0 will boost asset utilization. This will not only reduce resource requirements and wastage.

Motivation to develop such an operation management system which will enable industries to achieve the goal of "mass-production with mass-customization," which is the next challenge for the industry. A platform that makes it possible. The manufacturing platform will interconnect and enable interaction between the pillars of Manufacturing (Suppliers, Co-Industries, Customers, and the Parent Industry). It is a system that, when plugged into the operation, offers a complete real-time and remote planning, monitoring, and decision-making solution.

2.7 Research Objectives

2.7.1. Overall Objective

The overall objective is to develop a platform based on "Cyber-Physical Systems" and "Internet of Things" technologies, which helpmanufacturing industries in faster, and more real-time data-driven decision making andintelligent manufacturing planning.

2.7.2. Intermediate Objectives

- Small or medium enterprise and large manufacturing industry would be interested in adopting this system to increase the demand for their products and hence the profit.
- Industries that provide customization of their products can produce a customized product on a large scale by alluring new customers over the globe interested in buying the same product.
- Customers form the demand pool and the ones involved in this system will be benefited as they can get easy recommendations of the product they want and at a lower comparative cost.
- Develop algorithms for communication between assets, in the cybernetwork,for operations planning, and demonstrate the feasibility of distributed operations planning for job scheduling.

- Suppliers can have a clearer and dynamic tab on the demand of products industries.
- Other industries would be seeking opportunities to collaborate and expand their business by involving in resource sharing.
- Develop a method and design a system for generalized intelligentgroup-based communications between assets in the industrial networkbased on the concept of the human social network, such as Whatsapp, Facebook, etc.
- Software industries would be interested in developing the applications and other software modules, etc. for the proposed system.
- The software can be used to simulate various possible scenarios and for the analysis of dependencies of different factors in collaborative Manufacturing.

2.8. Novelty

There is three prime innovation made in this project:

- Real-time decision-making system
- Smart communication network between Industry, Customer, Supplier, and Co-Industry.
- Distributed Planning Algorithms

The platformpraises the approach of Industry 4.0 byemploying Cyber-Physical Systems (CPS) and the Internet of Things(IoT) for real-time decision making and intelligent manufacturing management. The most important feature of the system is that it converts the physical entity into cyberelements without actually relying on embedded systems and does distributeoperations planning by attributing social intelligence to every pillar of the industry. Each pillar is social - it chooses to interact with only those other pillars that are relevant to it at that instant, and intelligent - it is aware of itsown state and that of differentfactorsof a pillar in real-time, based on which it can takeautonomous decisions.

The algorithms based on the social networkingconcept are developed for the manufacturing systems for improving theinformation flow between all the actors of the industry. This improved flow of information in the industry leads tohigher efficiency in manufacturing operations planningand more flexibility in responding to events such asfailure or fluctuation in demand, supply, etc. As all the factors of pillars arebrought online onto the shared social network, it is possible to monitor thestatus of any element, remotely.

CHAPTER 3. COLLABORATIVE MANUFACTURING PLATFORM

The collaborative manufacturing platform acts as a medium that connects the pillars of Manufacturing, which are Customer, Supplier, and Co-Industry. The aim is to enhance the smartness of existing models via incorporating technological enablers and integrating these models on a common platform. The model is specifically designed to serve the needs of attaining the concept of Mass Production along with Mass Customization.

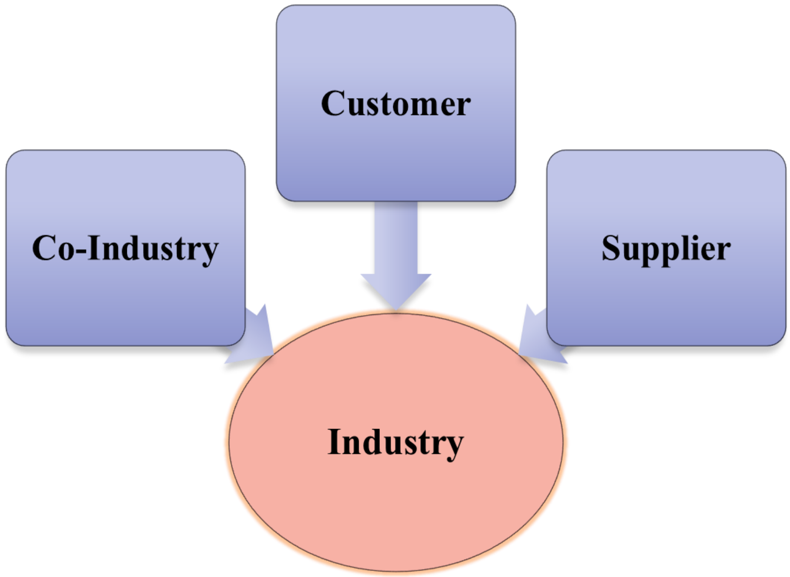


Fig.8. Pillars of Industry

The Collaborative Manufacturing Platform can be designed to work independently without human intervention and advantages being able to monitor, communicate events, and make smart decisions briskly in the future. The system includes the concept of Cyber-Physical Systems (CPSs). However, for the proposed system to function at the foreseen level of intelligence and independence, the system may take years of technological advancement and its implementation. Hence provision is made for an interface to be provided for human intervention. The algorithm can be easily implemented and assessed. More importantly, industries, as of now, can use this algorithm to test the project, dependencies of various factors involved in Manufacturing, and its impact on cost and operation. It provides and an all-in-one tool for optimization and decision making.

The system can is intense and handles the enormous number of factors and engage in their dynamic independencies. The model can be further divided at modular levels. Breakdown of the system at the modular level will yield the following sections:

- Customer-Industry Interaction
- Supplier-Industry Interaction
- Interaction with Neighbouring Industry

Overview of Cyber-Physical System:

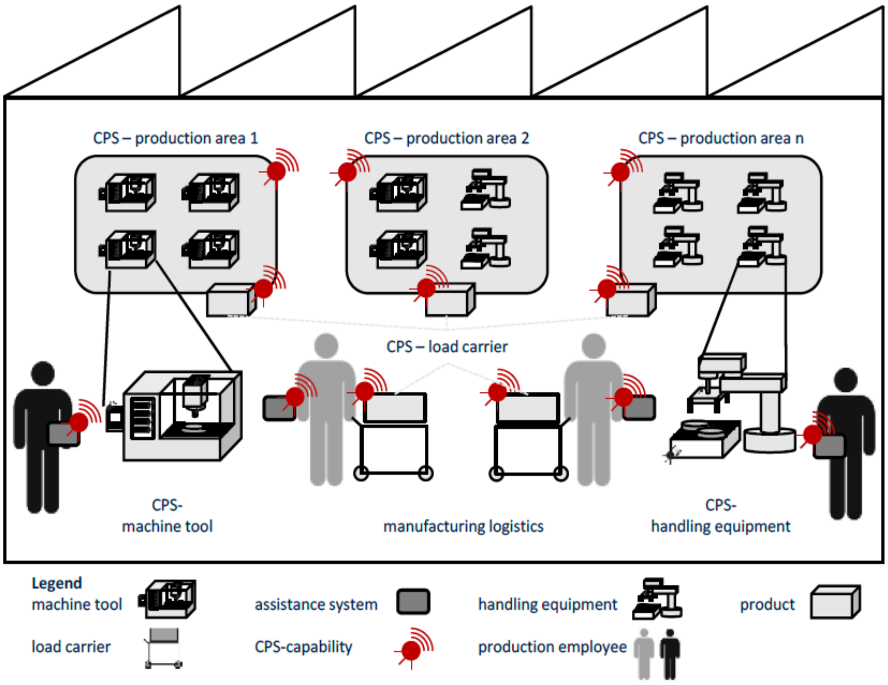


Fig.9. Cyber-Physical Production System [21]

3.1. Model

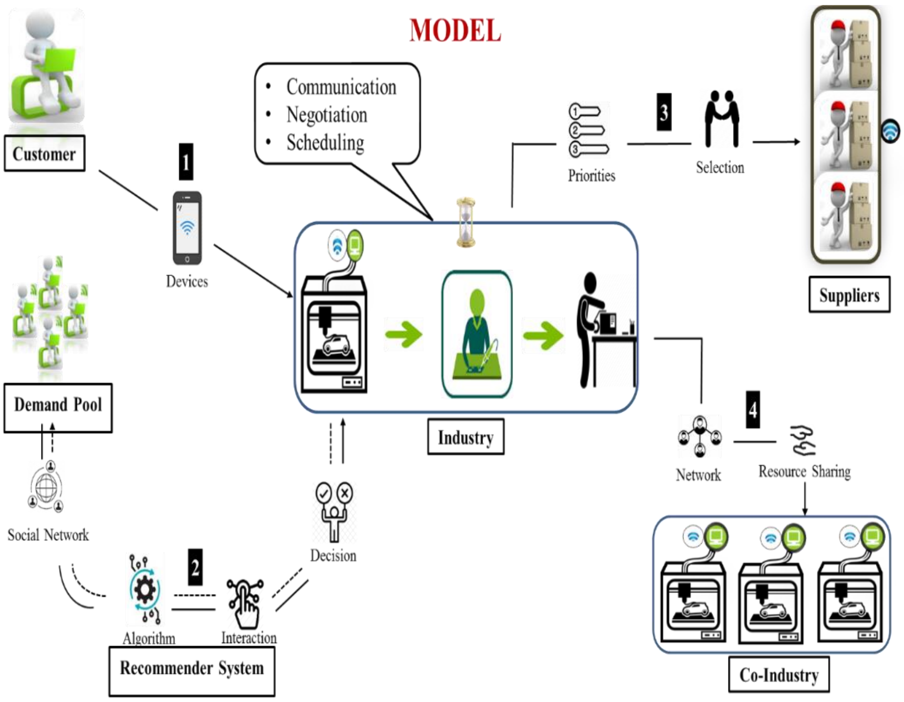


Fig.10. Collaborative Manufacturing Platform

For simulation purposes, we considered a model with a pool of customers that raise the demand, a parent industry, a total of 6 suppliers (3 of parent industry and 3 of co-industry), and three co-industries all having individual characteristic specifications. All the machines are connected. The parent industry produces a single type of product, which is an assembly of 2. The total product comes out after goring through 3 stations. All stations have specified characteristics. Suppliers havedifferent aspects, and raw material hasvariousaspects considered. The distance of each supplier and the neighbouring industry is considered to keep the account for transportation costs. The model is flexible, perfectly suitable for the study of dependencies and the impact of elements in the system.

The model was considered to visualize the changes that this Collaborative Manufacturing Platform will induce in Manufacturing and how variable demand can be dynamically managed and cost minimized.

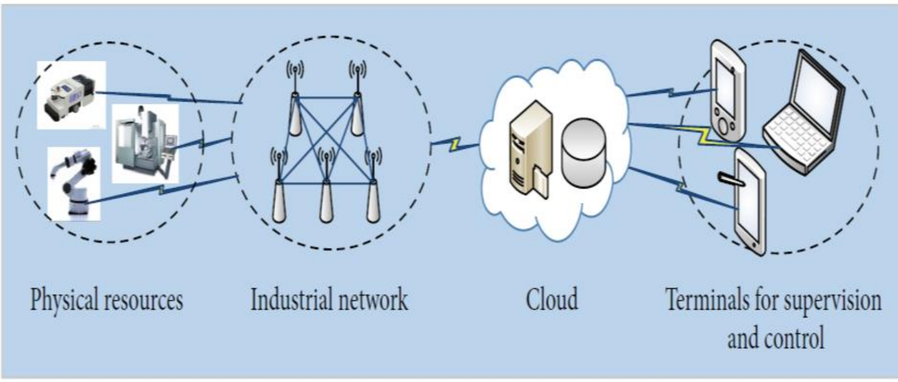


Fig.11. A Framework of the smart factory of Industry 4.0 [33].

3.2. Approaches for Increasing the demand

There are two types of approaches:

- Mass Production Approach (MPA)
- Available Capacity Approach (ACA)

3.2.1. Mass Production Approach (MPA)

In this approach, we have considered the industry is fully accessible for mass production. The Schedule of Industry depends on the increasing demand by the algorithm, and no other product schedule is available. The industry is fully open. The algorithm calculates all the production schedule. The number of customer approach does not depend on a convenient day.

3.2.2. Available Capacity Approach (ACA)

In this approach, we have considered the industry is available according to the convenient schedule days. We calculate the available capacity according to the vacant days in which no production is done. The industry should approach how many number customers to meet the available capacity so that the industry resources will be utiles well enough to make a good profit from it—all it calculated through algorithm.

3.3. Working

3.3.1. Working of Mass Production Approach (MPA)

- The customer generates initial demand, and the parent industry checks it against the inventory department and availability of machines and the current schedule of the industry.
- Supplier selection is made by analyzing the priority factor for the initial demand.
- The time and cost of production (product) for this demand is calculated.
- To increase the low initial demand, the parent industry smart machine by using the algorithm tries to increase the demand through a recommender system fig.3.2.
- Using previous data (customers who have search such kind of product), data analysis is done, and new customers are approached who are given an offer.
- Simulation of this is done by using a probability distribution model, which is based on the general probabilities.
- By negotiation, and applying all the prospects, the new demand is generated, which becomes the final demand.
- Demand pool is generated, and by applying all the probabilities algorithm gives the final demand.
- Cost breakdown and profit analysis are done against the increasing demand made by approaching the customer, so to increase the demand is made such that, where the cost per piece is low.
- To satisfy this final demand, supplier selection is made by analyzing the priority factor.
- If the parent industry is not able to manufacture the final demand within the delivery date, then they approach the co-industry and negotiates with them.
- Negotiation with co-industries is made for satisficing customer demand (demand above capacity) and increasing the trust value

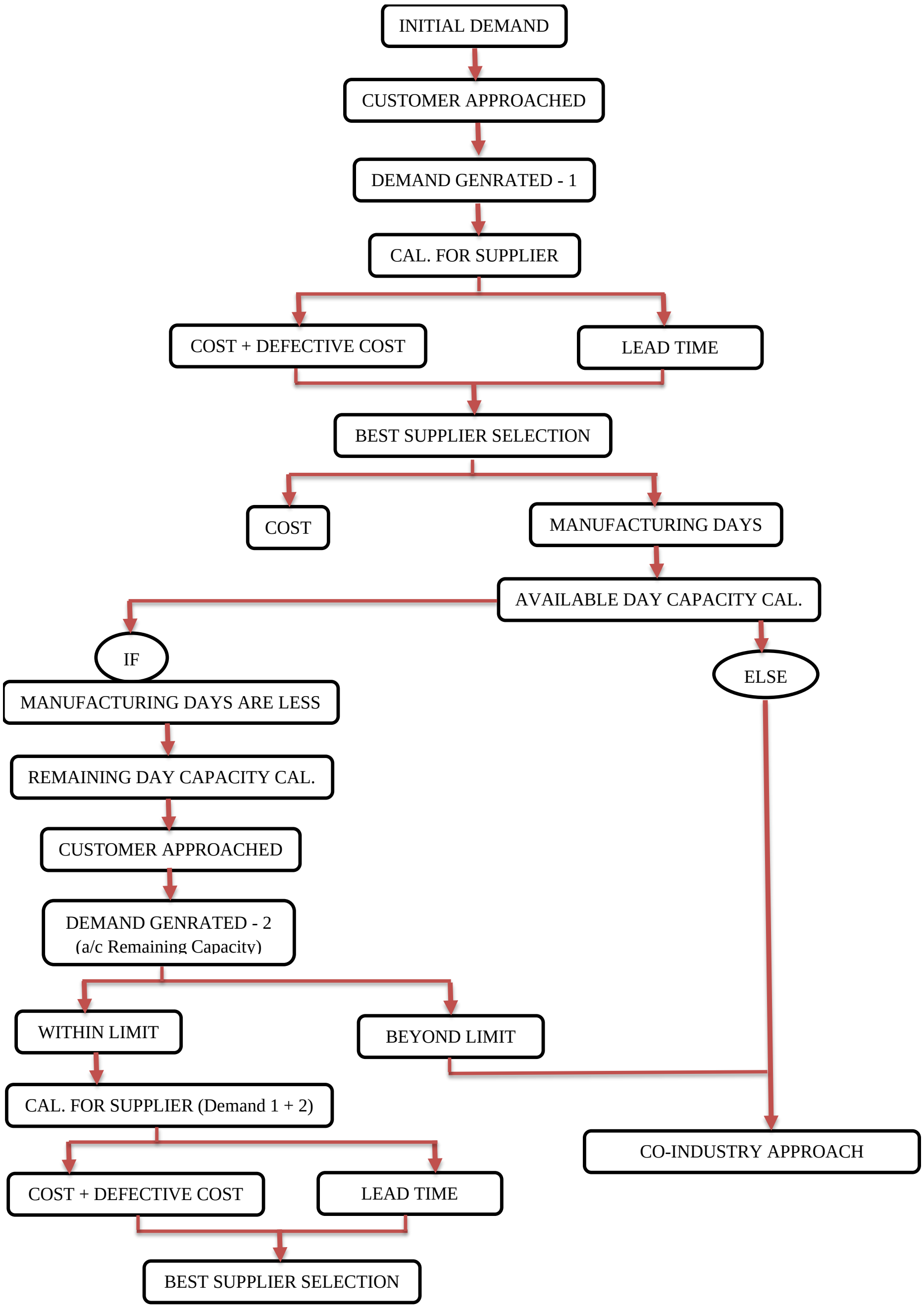
of the industry by providing the product before customers switch for other industries.

3.3.2. Working of Available Capacity Approach (ACA)

- The customer generates initial demand, and the parent industry checks it against the inventory department and availability of machines and the current schedule of the industry.
- Supplier selection is made by analyzing the priority factor for the initial demand.
- The time and cost of production (product) for this demand is calculated.
- If the initial demandis more than the available capacity of the industry, then the parent industry contacts the co-industries for the extra order, which is more than the available capacity and negotiates with them.
- Negotiation with co-industries is made for satisficing customer demand (demand above capacity) and increasing the trust value of the industry by providing the product before customers switch for other industries.
- If the initial demandis within the available capacity of the industry, then the parent industry machine through algorithm tries to increase the demand through a recommender system fig.3.2.
- The maximum capacity of the parent industry is calculated by considering all the failures and due dates(raw material and previous product). So the algorithm calculates the maximum number of products it can produce in an interval of time and approach the new customer according to that.
- Using previous data (customers who have search such kind of product), data analysis is done, and new customers are approached who are given an offer.
- Simulation of this is done by using a probability distribution model, which is based on the general probabilities.

- Demand pool is generated, and by applying all the probabilities algorithm gives the final demand
- Cost breakdown and profit analysis are done against the increasing demand made approaching the customer, so to increase the demand is made such that, where the cost per piece is low and by calculating the available capacity of the industry.
- Then for the final demand, scheduling, cost, and time calculation are done.
- To satisfy this final demand, supplier selection is made by analyzing the priority factor.

3.4. Process flow chart working of CMP of both approaches.



3.5. Characteristics of Industry and Pillars of Industry

3.5.1. Industry

The parentingindustry consists of three stations, the Manufacturing station, Assembly station, and Inspection and Packing station.

Assumptions:

- Product = 1, Industry = 1, Machine = 1, Stations = 3, Shifts = 2, Labour = 1
- Initial Demand = 1 to 10
- Customer approached = random (0,5000)
- Supplier = 6
- Setup Time/Part = 5 Minutes
- Manufacturing time = 20 Minutes
- Assembly time/Part = 2 Minutes
- Inspection & Packing time/Part = 3 Minutes
- Processing Cost/Unit = 20 Rs
- Overhead = 30 Rs
- Labour Cost(Rs) = 20/product
- Material Cost = Rs/gms (Depend on Supplier selection)
- Profit(%) = 25/Product
- Probability of defective product (7%)

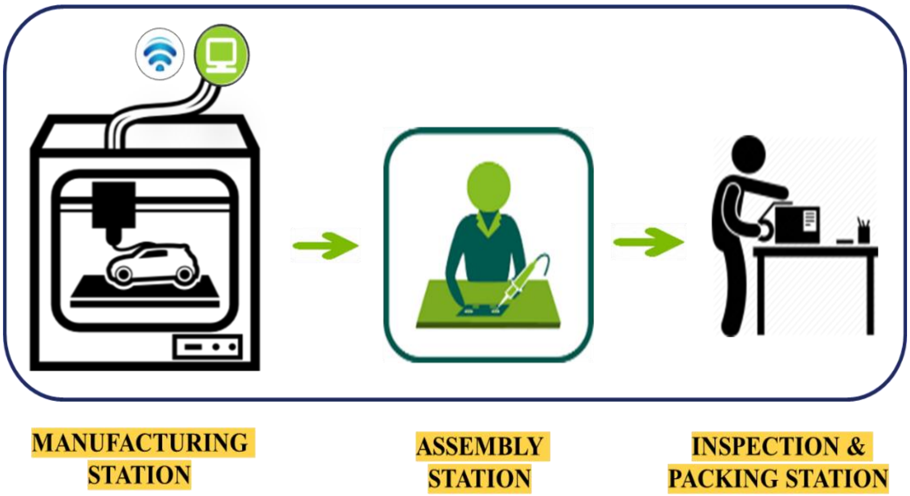


Fig.12. Parent Industry Layout

3.5.2. Customers

The service given to customers is the keyto business and marketing. Consumers write the review of companies product, interact with them via social media, and can simplybuyor go for alternatives products if their needs aren't being met. Globalization has increased the reach of industries, and people all over the globe can be contacted, and they can behave as a customer thereby increasing the demand. Customers in CMP are categorized as Loyal, Intermediate, and Likely to reject. Each category has specific probabilities of acceptance, rejection, return, and cancellation. Other factors included in this module are quantity based discounting (Higher the demand, higher will be the discount a firm can offer up to a specific limit) and Time Factor (Classification of demand pool based n time for the urgency of the requirement of product).Other factors considered are:

- Initial Demand
- Final Demand

  Customer Probability
    - Loyal (X%): - Accept (X%)
    - Intermediate (X%): - Accept (X%)
    - Reject (X%): - Accept (X%)
- Customer Types
    - Time-based
    - Cost-based
- Probability of influencing the customer (X%)
- Probability of cancellation of the order by the customer (X%)

Actual values taken are:

- Initial Demand = 1 - 5
- Final Demand

  Customer Probability:-
    - Loyal (25%):- Accept (60%)
    - Intermediate (35%):- Accept (25%)
    - Reject (40%):- Accept (15%)
- Customer Types
    - Time-based
    - Cost-based
- Probability of influencing the customer (60 to 80%)
- Probability of cancellation of the order by the customer (20%)

3.5.3. Supplier

Supplier and industry relationship has become progressivelycrucial in the total circumstances of the organization. Industries have generally decreased the number of suppliers they buy from to grow long-term, bilateral favourable deliberate partnerships with main suppliers. Each supplier would have different rates for different materials. Moreover, they may supply only a specific type of raw material.

The factors considered for supplier selection:

- Cost of raw material
- Time (Lead Time)
- Quantity based pricing
- Quality (Rating)
- Location (Transportation Cost)

Supplier Specification:

Supplier	**Price(Rs/gm)**	**Quality Factor**	**City**	**T + H cost(per kg)**	**Lead Time (Days)**
A	1.4	0.9 – 0.93	X	120	Vary with demand
B	1.2	0.98 – 0.94	Y	200	Vary with demand
C	1	0.93 – 0.88	Z	320	Vary with demand

Table 2. The parentindustry supplier with raw material specification

Supplier	Price(Rs/gm)	Quality Factor	City	T + H cost(per kg)	Lead Time (Days)
P	1.3	0.9 – 0.92	M	150	Vary with demand
Q	1.35	0.98 – 0.93	N	230	Vary with demand
R	1.1	0.95 – 0.88	O	330	Vary with demand

Table3. The co-industry supplier with raw material specification

Supplier		Material (No. of Spools)			
		5	10	20	35
A	**Discount (%)**	5	7	8	10
B		6	8	10	12
C		7	9	11	14

Table4. The supplier with discount specification

Considered factors with weightage for supplier selection:

Factor	Cost	Lead Time
Weightage (%)	70	30

***Table5. Factors with their weightage for* supplier selection**

3.5.4. Co-Industry

Resources from co-industries can be shared to maximize profit by increasing demand. As the machines are getting smarter, their failure can be predicted or predetermined through prognostics. Co-industry provides us with an alternative workplace with its machines and infrastructure. We can direct our jobs to there for further processing in the case of machine failure or the demand got raised more than the capacity of our workplace or the lack of spare machines in the case of machine downtime. Thus, co-industry plays an essential role in resource sharing and can be selected among all the available industries depending on their respective cost functions.

Primary factors considered for selection of the Co-Industry:

- Operation cost
- Facility location
- Raw material cost
- Availability

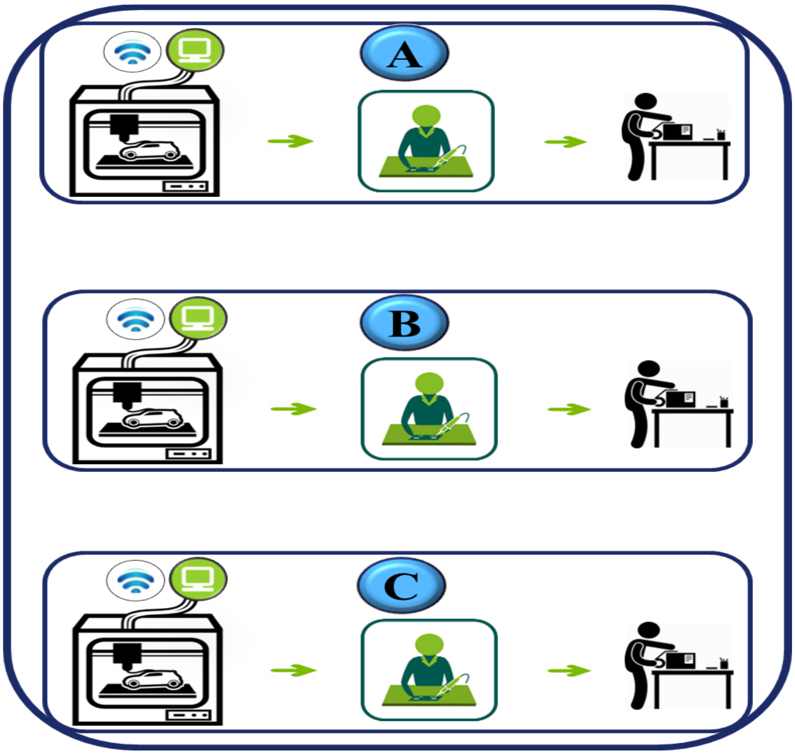


Fig.13. Co-Industries Layout

Actual values taken are:

- Availability of machines in co-industry (60%)
- Lead time for products from co-industry
- Probability of machine failure (5%)

- Probability of defective product (7%)

Considered factors with weightage for Co-Industry selection:

Factor	**Cost**	**Lead Time**
Weightage (%)	65	35

***Table6. Factors with their weightage*for Co-Industry selection**

CHAPTER 4. RESULTS AND DISCUSSION

The number of customers to be approached with a certain probability of acceptance is determined by iterating possibilities with expectations and uncertainties of various types of customers. The number of customers to approach depends upon the approach of the maximum net profit,which can help industry gain.

As the demand is deficient (close to zero), the cost per piece is very high as the price of transportation of raw material for a smaller number of products dominates. For such cases, inventory can be used. Cost per piece keeps on decreasing as the number of products manufacture in the parent industry itself increases until the maximum capacity is attained. But the due date, which is estimated or manage to convince the customer with delivery, plays a crucial role in the scheduling of production.

4.1. Mass Production Approach (MPA) Model-1

It has fixed values for all types of probabilities which had taken into account which are mentionedbelow.

Discount	0	5	8	10	12	15
Demand	3	18.28	48.34	79.4	155.79	232.2
Net Profit	414.725	1232.69	2731.65	3632.26	4963.71	4572.68

Table 7. Parameter of MPA model-1 for result analysis

Probability value for Model-1:

- Customer Probability:-
  - Loyal (25%):- Accept (60%)
  - Intermediate (35%):- Accept (25%)
  - Reject (40%):- Accept (15%)
- Probability of cancellation of the order by the customer (20%)
- Defective product probability (7%)

Table 8. Cost breakdown of model-1

Initial		3	3	3	3
Customer Approached		0	100	300	500
Customer Influence (60%)		0	60	180	300
Customer Category	Loyal (25%)	0	9	27	45
	Accept (60%)				
	Intermediate (35%)	0	5.25	15.75	26.25
	Accept (25%)				
	Reject (40%)	0	3.6	10.8	18
	Accept (15%)				
Customer after Influence		0	17.85	53.55	89.25
Probability of order cancelation	20%	0	14.28	42.84	71.4
Probability of defective product	7%	0	15.2796	45.8388	76.398
Final Demand		**3**	**18.2796**	**48.8388**	**79.398**
Wire (200 Grams)		600	3655.92	9767.76	15879.6
Ring		3.00	18.28	48.84	79.40
Material Cost	1.4	840	4862.3736	12717.6235	20452.9248
T + H Cost	120	72	438.7104	1172.1312	1905.552
Total		912	5301.084	13889.7547	22358.4768
Material Cost	1.2	720	4123.87776	10783.607	17149.968
T + H Cost	200	120	731.184	1953.552	3175.92
Total		840	4855.06176	12737.159	20325.888
Material Cost	1	600	3400.0056	8986.3392	14132.844
T + H Cost	320	192	1169.8944	3125.6832	5081.472
Total		792	4569.9	12112.0224	19214.316
Ring	12	36	219.3552	556.76232	886.08168
T + H Cost	0.3	0.9	5.48388	14.65164	23.8194
Total		36.9	224.83908	571.41396	909.90108
Ring	9	27	164.5164	413.176248	657.41544
T + H Cost	0.5	1.5	9.1398	24.4194	39.699
Total		28.5	173.6562	437.595648	697.11444
Ring	8	24	146.2368	363.360672	578.01744
T + H Cost	0.8	2.4	14.62368	39.07104	63.5184
Total		26.4	160.86048	402.431712	641.53584

OWN	DEMAND				
	3	18.28	48.84	79.4	15
T	500	500	500	500	
DEMAND)	912	4569.9	13889.755	22358.4768	429
	36.9	224.84	402.44	641.54	12
C DEMAND)	60	365.6	976.8	1588	1
T	60	365.6	976.8	1588	31
OST	90	548.4	1465.2	2382	
L	1658.9	6574.34	18210.995	29058.0168	496
	552.9666667	359.6466083	372.8704955	365.9699849	318.
	25	25	25	25	
COST/UNIT +	691.2083333	449.5582604	466.0881194	457.4624811	398.
PRICE	2073.625	8217.925	22763.74375	36322.521	620
NG DEMAND	0	5	8	10	
H DISCOUNT	691.2083333	427.0803474	428.8010698	411.716233	350.
CE WITH	2073.625	7807.02875	20942.64425	32690.2689	546
NIT	138.2416667	67.43373906	55.93057432	45.74624811	31.8
[	414.725	1232.68875	2731.64925	3632.2521	496

Table 9. Cost breakdown of model-1 (Con'd)

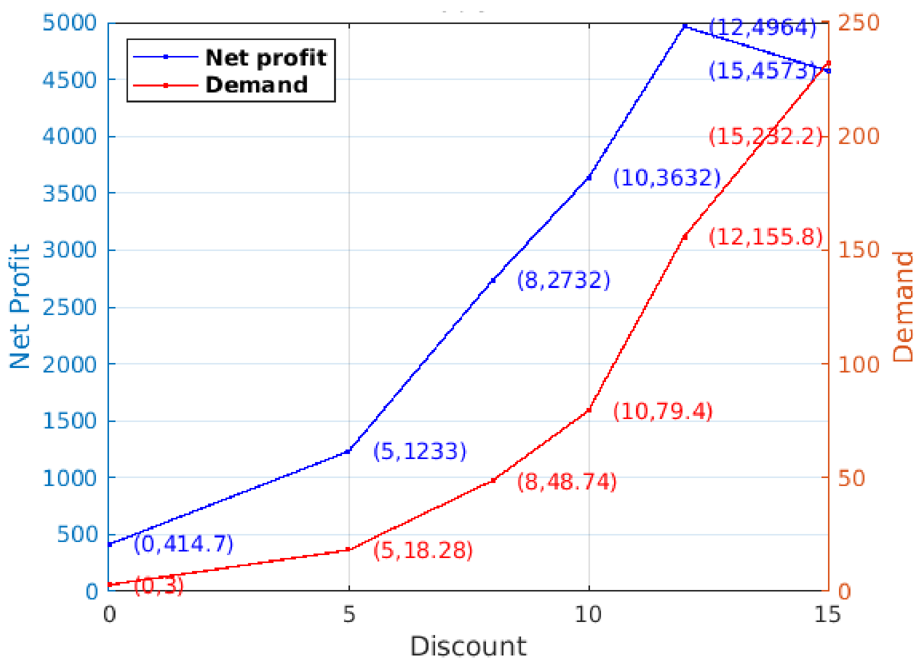


Fig.14. Results of Model 1

At pick point in the graph, the number of products to be produced reaches the maximum capacity according to the high net profit approach considering the discount limit on increasing demand. From the calculation, the approximate demand for which net profit will be high and how many customers should industry approached for that demand is get. If the demand increases beyond the expected demand, as an industry has to deliver a product the customer to the promised date of delivery, then the approached is made to co-industry. For a lower number of products from co-industry may not lead to a rise in profit of the company, this is due to a hefty cost of transportation and handling incurred on few products that are produced and transported by co-industry. But the number of products from resource sharing with co-industry is significant enough such that quantity discounts overshadow the rental cost; additional benefit can be attained, and all it can be done by negotiation with co-industry by smart machine.

All the cost breakdown is done by considering all cost factors like design, material, processing, labour, and overhead cost. Supplier selection here is made by selecting the low cost. From highlighted value limitation of discount with an increase in the number of demand can be seen.

4.2. Mass Production Approach (MPA) Model-2

This model is similar to model-1 but has different values for all types of probabilities, and the cost, discount range and transportation cost values are changed as it can be seen in Table 10, to see the difference in the resulting pattern.

Probability value for Model-2:

- Customer Probability:-
    - Loyal (20%):- Accept (70%)
    - Intermediate (50%):- Accept (30%)
    - Reject (30%):- Accept (20%)

- Probability of cancellation of the order by the customer (15%)
- Defective product probability (5%)

Required							
	Initial		5	5	5	5
	Customer Approached		0	100	200	500
	Customer Influence (50%)		0	60	120	300
	Customer Category	Loyal (20%)	0	8.4	16.8	42
		Accept (70%)				
		Intermediate (50%)	0	9	18	45
		Accept (30%)				
		Reject (30%)	0	3.6	7.2	18
		Accept (20%)				
	Customer after Influence		0	21	42	105
	Probability of order cancelation	15%	0	17.85	35.7	89.25
	Probability of defective product	5%	0	18.7425	37.485	93.7125
	Final Demand		**5**	**23.7425**	**42.485**	**98.7125**
Required	Wire (200 Grams)		1000	4748.5	8497	19742.5
	Ring		5.00	23.74	42.49	98.71
A	Material Cost	1.3	1300	5864.3975	10272.873	23612.03
	T + H Cost	100	100	474.85	849.7	1974.25
	Total		1400	6339.2475	11122.573	25586.28
B	Material Cost	1.2	1200	5356.308	9380.688	21321.9
	T + H Cost	180	180	854.73	1529.46	3553.65
	Total		1380	6211.038	10910.148	24875.55
C	Material Cost	1	1000	4416.105	7817.24	17570.825
	T + H Cost	300	300	1424.55	2549.1	5922.75
	Total		1300	5840.655	10366.34	23493.575
P	Ring	10	50	284.91	403.6075	918.02625
	T + H Cost	0.2	1	4.7485	8.497	19.7425
	Total		51	289.6585	412.1045	937.76875
Q	Ring	8	40	213.6825	319.4872	726.524
	T + H Cost	0.4	2	9.497	16.994	39.485
	Total		42	223.1795	336.4812	766.009
R	Ring	6	30	142.455	237.0663	538.97025
	T + H Cost	0.6	3	14.2455	25.491	59.2275

Table 10. Cost breakdown of model-2

Discount	0	5	8	10	12	15
Demand	5	23.74	42.49	98.71	154.94	192.43
Net profit	570.75	1623.36	2228.86	4199.29	4566.46	3530.17

Table 11. Parameter of MPA model-2 for result analysis

AKDOWN	DEMAND			
	5	23.7425	42.485	98.7125
COST	500	500	500	500
T(A/C DEMAND)	1400	6339.2475	11122.573	25586.28
COST	33	156.7005	262.5573	598.19775
T(A/C DEMAND)	100	474.85	849.7	1974.25
COST	100	474.85	849.7	1974.25
D COST	150	712.275	1274.55	2961.375
COST	2283	8657.923	14859.0803	33594.35275
UNIT	456.6	364.6592819	349.7488596	340.3252146
T (%)	25	25	25	25
NIT (COST/UNIT + FIT)	570.75	455.8241023	437.1860745	425.4065183
ING PRICE	2853.75	10822.40375	18573.85038	41992.94094
RASING DEMAND	**0**	**5**	**8**	**10**
T WITH DISCOUNT	570.75	433.0328972	402.2111885	382.8658665
CE WITH DISCOUNT	2853.75	10281.28356	17087.94235	37793.64684
ER UNIT	**114.15**	**68.37361535**	**52.46232894**	**42.54065183**
OFIT	**570.75**	**1623.360563**	**2228.862045**	**4199.294094**
red (Mins)	150	712.275	1274.55	2961.375
ired (Hr)	2.5	11.87125	21.2425	49.35625
livery Date	3	3	3	4

Table 12. Cost breakdown of model-2 (Con'd)

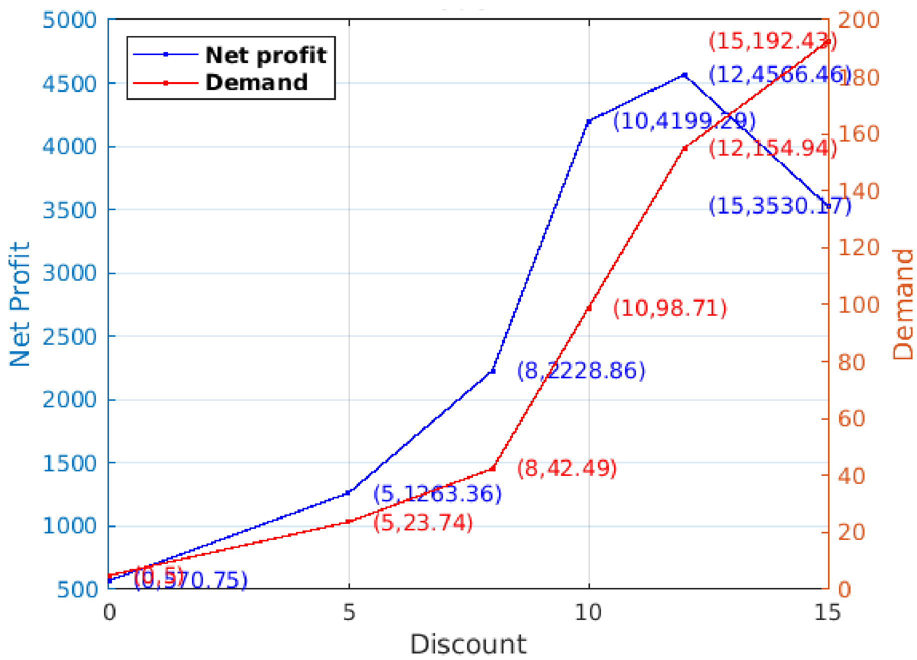


Fig.15. Results of Model 2

Here, the approach is the same that is mass production with high net profit. So it has been seen that by changing the values of probabilities doesn't make that much difference in the resulting pattern.

For both above model probability values are fixed, so the results are not that accurate, as probability can't be the same every time.

4.3. Mass Production Approach (MPA) and Available Capacity Approach (ACA) Model

Here Mass Production and Available Capacity approach are combined to get the best results, and this simulation is done by python programming. The values of probabilities are set in the range, and it generated randomly between this range. To get the more accuracy 1000 iteration are done and an average of it taken. Availability of industry is considered for ten days. Values are randomly generated (0-5000) customer approached to get the demand, the capacity of industry calculate for ten days (Change in available days can be done manual input) by calculating the time required to manufacture the single product, and delivery time to the customer is considered as ten days. Also, supplier lead time is taken as ten days, and also a range of lead time is set according to the order quantity for every supplier. Initial demand is generated randomly (1-10), also manually initial demand can be feed. The customer approached is calculated by considering different scenario that mass production but ten days of scheduling available. Also, through algorithm how many customers should be approached that with this available day capacity of industry, the manufacturing cost per product get reduce can be calculated. For that advantage of suppliers, the discount is the main factor. There are five different algorithms through which this is calculated, as the discount offer by the supplier will increase in stages, the values of customer approaches are increasing so as the demand. The results are shown in Table 13. Are average of 1000 iterations.

The results which obtained after 1000 iterations for parent industry are:

Initial Demand	Customer Approached	Total Demand	Industry (Cost/Piece)	Time of Industry
3.5	304.5	89	91.11439394	3
4.5	882.5	190.5	86.98014888	6.5
5.5	2173.5	339.5	84.70375672	11
3.5	2846	521.5	81.93303177	17
2	4468.5	710.5	80.79904228	22.5

Table13. Results for Parent Industry

From fig.16., cost per product is decreasing, but the increase in the number of demand quit high, but cost-reducing is low concerning that. With this model, we try to manufacture the product without increasing the profit percentage but by taking advantage of the discount offer by the supplier and the co-industry. From the calculation, the approximate demand for which net profit will be high (not always) and how many customers should industry approached for that demand is calculated. The ratio of reduction in the manufacturing cost concerning the increasing demand is low.

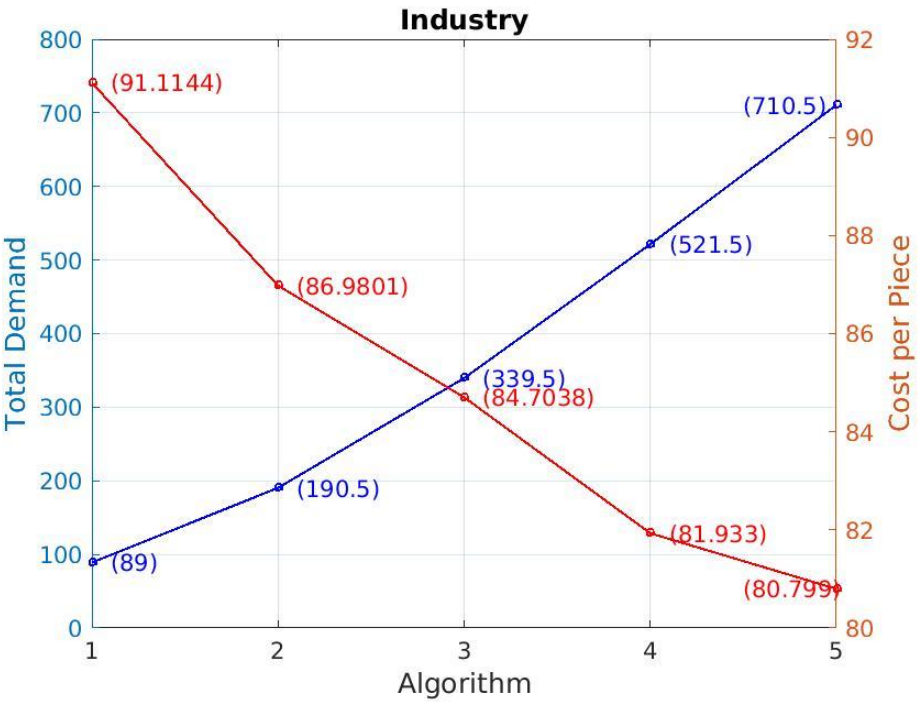


Fig.16. Total demand vs Cost/Product

The results which are got after 1000 iterations for co-industry are:

Outsourcing Qty	Co-Industry(Cost/Piece)	Lead Time of Co-Industry
54.5	117.3492437	3
17.5	398.15	3
19.5	294.0625	3
201.5	91.21394231	7
390.5	78.87718449	17

Table 14. Results for Co-Industry

Co-industry, as a pillar of this platform, has a high impact when parent industry has to outsource the demand. Results which get below have the assumption that co-industry also has ten days availability. More is outsourcing quantity, the lower is the cost, but the lead time is more. So the outsourcing from different co-industry (more then one industry) if the lead time of outsourcing quantity is more than the customer promiseddelivery date, so customer stay connected with industry and industry can gain the trust of the consumer.

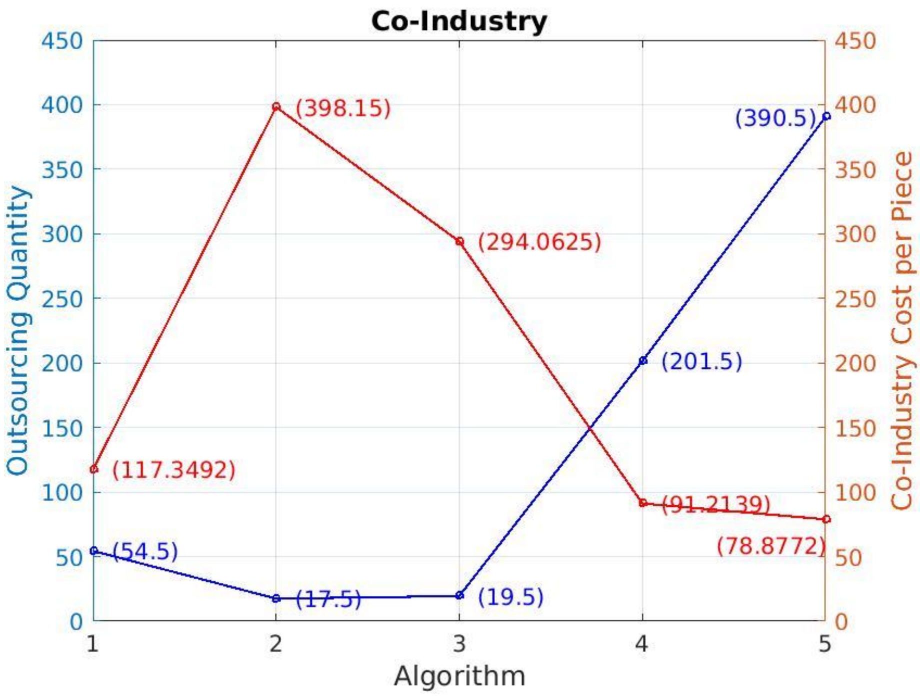


Fig.17. Outsourcing quantity vs Cost/Piece

Fluctuation in the outsourcing quantity is due to if the initial demand generated is low than the available manufacturing capacity then for final demand new customer approach is made. If the final demand is more than the available capacity,the intelligent machine makes contact with the co-industry and by negotiation outsourced the quantity. The customer approach made to fulfil the capacity sometime may attract more customer than expected, so the pick and drop in the outsourcing quantity and with respect to that change in the cost.

CHAPTER 5. CONCLUSION

5.1. Summary

The system helps in the execution of Industry 4.0irrespective of the preparedness of the infrastructure for this next revolution in the industry. The manufacturing sector is moving towards the fourth the industrial revolution. Cyber-Physical Systems (CPS) and the Internet of Things (IoT) are the primary pillars of this transformation. This work proposes the platform formation of a transient method. Characteristics advantages will get from the CMP include (i) Induced connections between a machine in the industrial network, (ii) Upgradation of the physical machine into a cyber-physical system, (iii) real-time operations planning. Using Collaborative Manufacturing Platform may lead to increased profit in the existing benefit.An overall rise in the number of demand and thus increases the profit for both the customers and industry.

Python programming based simulation has been developed in this work. Typical characteristics of the program include capacity calculation, availability of industry, failure of the machine, defective product, customer probability, cost analysis, real-time scheduling, etc. Cost analysis, according to a smart selection of supplier and co-industry every time is done with the change in demand. The intelligent selection of suppliers and neighbouring industry through the algorithm ensures best possible amalgamation of the lowest cost, best quality and availability.Data and service sharing can make effective use of the looseproduction resources to enlarge theutilization of the facilities and workforce of the industry, and knowledge sharing between companies can help them aimat their key competencies. The algorithm developed in this work is capable of all the decision-making ability and smart selection of supplier and co-industry. Parameters weightage can be managed according to the industry requirement.

5.2. Future Scope

The work can be expanded further by bringing in better and robust models to make predictions.In the present research, the algorithm developed is by considering the single machine and single component. Extending the current research by examining the failure, especially from the maintenance point of view. It will bring more parameters into account. Also, the weightage parameter can be monitored, and the new parameter can be introduced for more advances algorithm can be done and significantly increase the computationcomplexity.

Eventually, the essential domain of Industry 4.0 research,which increasingly focuses on developing more data collection and data mining to build up a more advanced intelligent operations planning system for next-generation Manufacturing.

APPENDICES

```
import random

import math

import decimal

from xlwt import Workbook

wb = Workbook()

sheet1 = wb.add_sheet('Sheet 1', cell_overwrite_ok=True)


#TO GENERATE THE TABLE WITH 1000 ITERATION

Titles = ('Initial Demand','Customer Approached', 'Total Demand', 'Industry(Cost/Piece)','Time of Industry', 'Outsourcing Qty', 'Co-Industry(Cost/Piece)', 'Lead Time of Co-Industry')

j = 0
```

```
for i in Titles:
    sheet1.write(0, j, i)
    j= j+1


for iteration in range(1,1001):


    #initial_demand = int(input("Enter the Initial Demand = "))
    initial_demand = int(random.randint(1,10))
    sheet1.write(iteration, 0, initial_demand)
    #lead_time = int(input("Max Lead Time Allowed = "))
    #available_schedule_days = int(input('Number of Available Days = 
'))
    #available_schedule_days = int(random.randint(5,30))
    available_schedule_days = 10
    #shifts_of_industry = int(input('Number of Shifts  = '))
    shifts_of_industry = 2


#MATERIAL CALCULATION
    def one():
        material_cost_supp_A = initial_demand * 200 * 1.4
        material_cost_supp_B = initial_demand * 200 * 1.25
        material_cost_supp_C = initial_demand * 200 * 1.1
        Transportation_cost_A = initial_demand * .2 * 120
        Transportation_cost_B = initial_demand * .2 * 200
        Transportation_cost_C = initial_demand * .2 * 320


 #CUSTOMER APPROACHED TO INCREASED THE DEMAND
        while True:
            customer_approached = random.randrange(0,5000)
            sheet1.write(iteration, 1, customer_approached)
```

```
    print("Customer Approached to increase the Demand = ",customer_approached)

    customer_influence = customer_approached * random.uniform(0.6,0.8)

    #print("Customer after influence = ", customer_influence)

    #loyal = 0.5 * 0.8 * customer_influence

    #intermediate = 0.3 * 0.5 * customer_influence

    #not_confirmed = 0.2 * 0.2 * customer_influence


    loyal = 0.5 * (random.uniform(0.65,0.8)) * customer_influence

    intermediate = 0.3 *(random.uniform(0.4,0.65)) * customer_influence

    not_confirmed = 0.2 * (random.uniform(0.05,0.4)) * customer_influence

    #print("Loyal Customer = ",loyal)

    #print("Intermediate Customer = ",intermediate)

    #print("Not Confirmed Customer = ",not_confirmed)

    customer_distribution = (loyal + intermediate + not_confirmed)

    #print("Customer after Distribution = ",customer_distribution)

    order_cancellation_probability = (customer_distribution * (random.uniform(0.15,0.3)))

    order_after_cancellation = (customer_distribution - order_cancellation_probability)

    #print("Demand after Order Cancellation =",order_after_cancellation)

    final_demand = order_after_cancellation

    #print("Final Demand = ",final_demand)

    total_demand = math.ceil(initial_demand + final_demand)

    print("Total Demand =",total_demand)

    sheet1.write(iteration, 2, total_demand)


    if (total_demand > 35) and (total_demand < 51):
```

```
        break
      print()

   # discount of suppliers

#SUPPLIER MATERIAL COST CALCULATION BY CONSIDERING THE DISCOUNT
   if material_cost_supp_A>0:

      if (5 * 10 * 200 * 1.4) <= material_cost_supp_A < (5 * 20 * 200 * 1.4):
        discount_by_final_supplier_A = (material_cost_supp_A*0.05)
      elif (5 * 20 * 200 * 1.4) <= material_cost_supp_A < (5 * 40 * 200 * 1.4):
        discount_by_final_supplier_A = (material_cost_supp_A*0.10)
      elif (5 * 40 * 200 * 1.4) <= material_cost_supp_A < (5 * 70 * 200 * 1.4):
        discount_by_final_supplier_A = (material_cost_supp_A * 0.15)
      elif (5 * 70 * 200 * 1.4) <= material_cost_supp_A < (5 * 110 * 200 * 1.4):
        discount_by_final_supplier_A = (material_cost_supp_A * 0.20)
      elif (5 * 110 * 200 * 1.4) <= material_cost_supp_A < (5 * 160 * 200 * 1.4):
        discount_by_final_supplier_A = (material_cost_supp_A * 0.24)
      elif material_cost_supp_A >= (5 * 160 * 200 * 1.4):
        discount_by_final_supplier_A = (material_cost_supp_A * 0.27)
      else:
        discount_by_final_supplier_A = 0
```

```
            #print("Discount of Supplier A for Total Demand = ",
discount_by_final_supplier_A)

        else:

            print("No Discount by Supplier A")



        if material_cost_supp_B>0:



            if (5 * 10 * 200 * 1.25) <= material_cost_supp_B < (5 * 20 *
200 * 1.25):

                discount_by_final_supplier_B =
(material_cost_supp_B*0.06)

            elif (5 * 20 * 200 * 1.25) <= material_cost_supp_B < (5 * 40 *
200 * 1.25):

                discount_by_final_supplier_B =
(material_cost_supp_B*0.11)

            elif (5 * 40 * 200 * 1.25) <= material_cost_supp_B < (5 * 70 *
200 * 1.25):

                discount_by_final_supplier_B= (material_cost_supp_B *
0.16)

            elif (5 * 70 * 200 * 1.25) <= material_cost_supp_B < (5 * 110
* 200 * 1.25):

                discount_by_final_supplier_B= (material_cost_supp_B *
0.21)

            elif (5 * 110 * 200 * 1.25) <= material_cost_supp_B < (5 * 160
* 200 * 1.25):

                discount_by_final_supplier_B= (material_cost_supp_B *
0.25)

            elif material_cost_supp_B >= (5 * 160 * 200 * 1.25):

                discount_by_final_supplier_B = (material_cost_supp_B *
0.28)

            else:

                discount_by_final_supplier_B = 0

            #print("Discount of Supplier B for Total Demand = ",
discount_by_final_supplier_B)

        else:
```

```
        print("No Discount by Supplier B")

    if material_cost_supp_C>0:

        if (5 * 10 * 200 * 1.1) <= material_cost_supp_C < (5 * 20 *
200 * 1.1):
            discount_by_final_supplier_C =
(material_cost_supp_C*0.07)
        elif (5 * 20 * 200 * 1.1) <= material_cost_supp_C < (5 * 40 *
200 * 1.1):
            discount_by_final_supplier_C =
(material_cost_supp_C*0.12)
        elif (5 * 40 * 200 * 1.1) <= material_cost_supp_C < (5 * 70 *
200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.17)
        elif (5 * 70 * 200 * 1.1) <= material_cost_supp_C < (5 * 110 *
200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.23)
        elif (5 * 110 * 200 * 1.1) <= material_cost_supp_C < (5 * 160
* 200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.27)
        elif material_cost_supp_C >= (5 * 160 * 200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.3)
        else:
            discount_by_final_supplier_C = 0
        #print("Discount of Supplier C for Total Demand = ",
discount_by_final_supplier_C)
    else:
        print("No Discount by Supplier C")
```

#TOTAL MATERIAL COST OF EACH SUPPLIER

```
    Total_material_cost_final_A = (material_cost_supp_A + Transportation_cost_A - discount_by_final_supplier_A)

    Total_material_cost_final_B = (material_cost_supp_B + Transportation_cost_B - discount_by_final_supplier_B)

    Total_material_cost_final_C = (material_cost_supp_C + Transportation_cost_C - discount_by_final_supplier_C)


    #QUALITY FACTOR OF SUPPLIER

    quality_of_supp_A = random.uniform(.94,.9)

    quality_of_supp_B = random.uniform(.97,.91)

    quality_of_supp_C = random.uniform(.96,.88)


#DEFECT CONSIDERATION

    defective_rate_A = (1-quality_of_supp_A)

    defective_rate_B = (1-quality_of_supp_B)

    defective_rate_C = (1-quality_of_supp_C)


    no_products_to_extra_manf_A = math.ceil(total_demand * defective_rate_A)

    no_products_to_extra_manf_B = math.ceil(total_demand * defective_rate_B)

    no_products_to_extra_manf_C = math.ceil(total_demand * defective_rate_C)

    print("Number of Products to extra Manufactur choosing Supplier A = ",no_products_to_extra_manf_A)

    print("Number of Products to extra Manufactur choosing Supplier B = ",no_products_to_extra_manf_B)

    print("Number of Products to extra Manufactur choosing Supplier C = ",no_products_to_extra_manf_C)


    #LEAD TIME OF SUPPLIERS FOR DIFFERENT DEMAND

    lead_time_supplier_A = 0
```

```
lead_time_supplier_B = 0
lead_time_supplier_C = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_A = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_A = 5
elif 251<= total_demand <= 450:
    lead_time_supplier_A = 6
elif 451<= total_demand <= 700:
    lead_time_supplier_A = 8
elif 701<= total_demand <= 1000:
    lead_time_supplier_A = 10
elif total_demand >= 1001:
    lead_time_supplier_A = 11
else:
    lead_time_supplier_A = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_B = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_B = 5
elif 251<= total_demand <= 450:
    lead_time_supplier_B = 7
elif 451<= total_demand <= 700:
    lead_time_supplier_B = 9
elif 701<= total_demand <= 1000:
    lead_time_supplier_B = 10
elif total_demand >= 1001:
```

```
        lead_time_supplier_B = 12
    else:
        lead_time_supplier_B = 0


    if 1 <= total_demand <= 100:
        lead_time_supplier_C = 4
    elif 101<= total_demand <= 250:
        lead_time_supplier_C = 5
    elif 251<= total_demand < 450:
        lead_time_supplier_C = 8
    elif 451<= total_demand <= 700:
        lead_time_supplier_C = 10
    elif 701<= total_demand <= 1000:
        lead_time_supplier_C = 11
    elif total_demand >= 1001:
        lead_time_supplier_C = 13
    else:
        lead_time_supplier_C = 0


    #CALCULATION OF TOTAL COST REQUIRED TO MANUFACTURED THE NUMBER OF DEMAND BY TAKING ALL SUPPLIER MATERIAL
    processing_cost = 35
    overhead_cost = 35
    labour_cost = 30


    material_and_trans_cost_A = (Total_material_cost_final_A/total_demand)
    product_cost_A = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_A)
```

```
    total_cost_for_A = Total_material_cost_final_A + (no_products_to_extra_manf_A * material_and_trans_cost_A) + (no_products_to_extra_manf_A * product_cost_A)


    material_and_trans_cost_B = (Total_material_cost_final_B/total_demand)

    product_cost_B = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_B)

    total_cost_for_B = Total_material_cost_final_B + (no_products_to_extra_manf_B * material_and_trans_cost_B) + (no_products_to_extra_manf_B * product_cost_B)


    material_and_trans_cost_C = (Total_material_cost_final_C/total_demand)

    product_cost_C = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_C)

    total_cost_for_C = Total_material_cost_final_C + (no_products_to_extra_manf_C * material_and_trans_cost_C) + (no_products_to_extra_manf_C * product_cost_C)


    #print('Total Cost for Supplier A = ',total_cost_for_A)

    #print('Total Cost for Supplier B = ',total_cost_for_B)

    #print('Total Cost for Supplier C = ',total_cost_for_C)


# WEIGHTAGE CALCULATION CONSIDERING THE LEAD TIME

    wt_lead_time_a = .3

    wt_lead_time_b = .3

    wt_lead_time_c = .3


    if(lead_time_supplier_A < lead_time_supplier_B) and (lead_time_supplier_A < lead_time_supplier_C):

        #print("Supplier A has min lead time")

        wt_lead_time_b = (.3 - (0.3*((lead_time_supplier_B - lead_time_supplier_A)/lead_time_supplier_B )))
```

```
            wt_lead_time_c = (.3 - (0.3*((lead_time_supplier_C -
lead_time_supplier_A)/lead_time_supplier_C )))

        elif(lead_time_supplier_B < lead_time_supplier_A) and
(lead_time_supplier_B < lead_time_supplier_C):

            #print("Supplier B has min lead time")

            wt_lead_time_a = (.3 - (0.3*((lead_time_supplier_A -
lead_time_supplier_B)/lead_time_supplier_A )))

            wt_lead_time_c = (.3 - (0.3*((lead_time_supplier_C -
lead_time_supplier_B)/lead_time_supplier_C )))

        elif(lead_time_supplier_C < lead_time_supplier_A) and
(lead_time_supplier_C < lead_time_supplier_B):

            #print("Supplier C has min lead time")

            wt_lead_time_a = (.3 - (0.3 * ((lead_time_supplier_A -
lead_time_supplier_C) / lead_time_supplier_A)))

            wt_lead_time_b = (.3 - (0.3 * ((lead_time_supplier_B -
lead_time_supplier_C) / lead_time_supplier_B)))

        #print("Minimum Lead time =
",(min(lead_time_supplier_A,lead_time_supplier_B,lead_time_supplie
r_C)))


        wt_material_cost_a = .7

        wt_material_cost_b = .7

        wt_material_cost_c = .7


        if(total_cost_for_A < total_cost_for_B) and (total_cost_for_A <
total_cost_for_C):

            #print("Supplier A has min total material cost for Initial
Demand")


            wt_material_cost_b = (.7 - (0.7*((total_cost_for_B -
total_cost_for_A)/total_cost_for_A )))

            wt_material_cost_c = (.7 - (0.7*((total_cost_for_C -
total_cost_for_A)/total_cost_for_A )))

        elif(total_cost_for_B < total_cost_for_C) and (total_cost_for_B <
total_cost_for_A):
```

```
            #print("Supplier B has min total material cost for Initial Demand")
            wt_material_cost_a = (.7 - (0.7 * ((total_cost_for_A - total_cost_for_B) / total_cost_for_B)))
            wt_material_cost_c = (.7 - (0.7 * ((total_cost_for_C - total_cost_for_B) / total_cost_for_B)))
        elif(total_cost_for_C < total_cost_for_A) and (total_cost_for_C < total_cost_for_B):
            #print("Supplier C has min total material cost for Initial Demand")
            wt_material_cost_a = (.7 - (0.7 * ((total_cost_for_A - total_cost_for_C) / total_cost_for_C)))
            wt_material_cost_b = (.7 - (0.7 * ((total_cost_for_B - total_cost_for_C) / total_cost_for_C)))


#BEST SUPPLIER CALCULATION BY CALCULATING THE WEIGHTAGE
        supplier_A = ((wt_material_cost_a + wt_lead_time_a) * 100)
        #print("Supplier A weightage = " , supplier_A , "%")
        supplier_B = ((wt_material_cost_b + wt_lead_time_b) * 100)
        #print("Supplier B weightage = " , supplier_B , "%")
        supplier_C = ((wt_material_cost_c + wt_lead_time_c) * 100)
        #print("Supplier C weightage = " , supplier_C , "%")


        if (supplier_A > supplier_B) and (supplier_A > supplier_C):
            print("Supplier A is the best...!!!")
            #price = total_cost_for_A
        elif(supplier_B > supplier_A) and (supplier_B > supplier_C):
            print("Supplier B is the best...!!!")
            #price = total_cost_for_B
        elif (supplier_C > supplier_A) and (supplier_C > supplier_B):
            print("Supplier C is the best...!!!")
            #price = total_cost_for_C
```

```
supp_weight = (supplier_A,supplier_B,supplier_C)

cost =
(Total_material_cost_final_A,Total_material_cost_final_B,Total_mate
rial_cost_final_C)

best_supp = max(supplier_A,supplier_B,supplier_C)

#print ("Best Supplier Weightage = ",best_supp)

index_of_best_supplier = supp_weight.index(best_supp)

material_cost_of_best_supplier =
cost[int(index_of_best_supplier)]

print('Material Cost of Best Supplier =
',material_cost_of_best_supplier)


#COST PARAMETERS

processing_cost = 35

overhead_cost = 35

labour_cost = 30

material_and_trans_cost =
(material_cost_of_best_supplier/total_demand)

product_cost = (processing_cost + overhead_cost + labour_cost +
material_and_trans_cost)

sheet1.write(iteration, 3, product_cost)

product_cost_total = (total_demand * product_cost)

product_price = (product_cost * 1.5)

product_price_of_total_demand = (total_demand * product_price)

print ("Cost of Single Product = ",product_cost)

print ("Cost of Total Demand = ",product_cost_total)

print ("Price of Single Product = ",product_price)

print("Price of Total Demand =
",product_price_of_total_demand)


#TIME PARAMETERS

setup_time = 5
```

```
        manufacturing_time = 20

        assembly_time = 2

        inspection_and_packing_time = 3

        shift_hrs = 8


#CAPACITY CALCULATION OF INDUSTRY

        one_day_capacity_ind = ((shifts_of_industry * shift_hrs * 60)/30)

        capacity_of_industry = ((available_schedule_days *
shifts_of_industry * shift_hrs * 60)/30)

        time_for_1_part = (setup_time + manufacturing_time +
assembly_time + inspection_and_packing_time)

        time_for_total_demand = total_demand * time_for_1_part

        no_of_days_for_manf =
((math.ceil(time_for_total_demand/(60*(shift_hrs*shifts_of_industry))
)))

        sheet1.write(iteration, 4, no_of_days_for_manf)

        print("Estimated Time for cost factor Demand Manufacturing = ",
time_for_total_demand , "Minutes")

        print("Estimated Days for cost factor Demand Delivery = ",
no_of_days_for_manf , "Days")

        remaining_days_capacity = ((available_schedule_days -
no_of_days_for_manf) * one_day_capacity_ind)

        if (no_of_days_for_manf < available_schedule_days):


            # TO INCREASE THE DEMAND TO SATISFY THE
AVAILABILITY AGAIN APPROCHING THE CUSTOMER

            while True:

                customer_approached = random.randint(10,5000)

                #print("Customer Approached to increase the Demand to
Fullfil Capacity = ",customer_approached)

                customer_influence = customer_approached * 0.8

                loyal = 0.5 * 0.85 * customer_influence

                intermediate = 0.3 * 0.55 * customer_influence
```

```
                not_confirmed = 0.2 * 0.2 * customer_influence
                #print("Loyal Customer = ",loyal)
                #print("Intermediate Customer = ",intermediate)
                #print("Not Confirmed Customer = ",not_confirmed)
                customer_distribution = (loyal + intermediate +
not_confirmed)
                #print("Customer after Distribution =
",customer_distribution)
                order_cancellation_probability = (customer_distribution *
(random.uniform(0.15,0.3)))
                order_after_cancellation = (customer_distribution -
order_cancellation_probability)
                #print("Demand after Order Cancellation
=",order_after_cancellation)
                final_demand = order_after_cancellation
                #print("Final Demand = ",final_demand)
                total_demand_cap = math.ceil(final_demand)
                #print("Total Demand =",total_demand_cap)
                if ((remaining_days_capacity*.8) < total_demand_cap) and
(total_demand_cap < (remaining_days_capacity * 1.4)):
                    print("Capacity of Industry for Available Schedule Days =
", capacity_of_industry)
                    print("Customer Approached to increase the Demand to
Fullfil Capacity = ", customer_approached)
                    print("Total Demand for Capacity Fullfilment of Industry
= ", total_demand_cap)
                    break


#MANUFACURING TIME CALCULATION FOR THE
GENRATED DEMAND
            total_time_for_demand_cap_mins = (total_demand_cap *
time_for_1_part)
            total_time_for_demand_cap_days =
((math.ceil(total_time_for_demand_cap_mins/(60*(shift_hrs*shifts_of
_industry)))))
```

```
print("Estimated Time for Capcity Fulfillment Manufacturing = ", total_time_for_demand_cap_mins , "Minutes")

print("Estimated Days for Delivery of Capacity Fulfillment = ", total_time_for_demand_cap_days , "Days")


#CO-INDUSTRY (COST CALCULATION)

if (total_demand_cap > remaining_days_capacity):


    qty = (total_demand_cap - remaining_days_capacity)

    sheet1.write(iteration, 5, qty)

    material_cost_supp_A = initial_demand * 200 * 1.4

    material_cost_supp_B = initial_demand * 200 * 1.25

    material_cost_supp_C = initial_demand * 200 * 1.1

    Transportation_cost_A = initial_demand * .2 * 120

    Transportation_cost_B = initial_demand * .2 * 200

    Transportation_cost_C = initial_demand * .2 * 320

    material_cost_supp_P = qty * 200 * 1.3

    material_cost_supp_Q = qty * 200 * 1.35

    material_cost_supp_R = qty * 200 * 1.1

    Transportation_cost_P = qty * .2 * 150

    Transportation_cost_Q = qty * .2 * 230

    Transportation_cost_R = qty * .2 * 330


    # DISCOUNT GIVEN BY SUPPLIERS TO CO-INDUSTRY

    if material_cost_supp_A>0:

        if (5 * 10 * 200 * 1.4) <= material_cost_supp_A < (5 * 20 * 200 * 1.4):

            discount_by_final_supplier_A = (material_cost_supp_A*0.05)

        elif (5 * 20 * 200 * 1.4) <= material_cost_supp_A < (5 * 40 * 200 * 1.4):
```

```
                    discount_by_final_supplier_A =
(material_cost_supp_A*0.10)

                elif (5 * 40 * 200 * 1.4) <= material_cost_supp_A < (5 *
70 * 200 * 1.4):

                    discount_by_final_supplier_A = (material_cost_supp_A
* 0.15)

                elif (5 * 70 * 200 * 1.4) <= material_cost_supp_A < (5 *
110 * 200 * 1.4):

                    discount_by_final_supplier_A = (material_cost_supp_A
* 0.20)

                elif (5 * 110 * 200 * 1.4) <= material_cost_supp_A < (5 *
160 * 200 * 1.4):

                    discount_by_final_supplier_A = (material_cost_supp_A
* 0.24)

                elif material_cost_supp_A >= (5 * 160 * 200 * 1.4):

                    discount_by_final_supplier_A = (material_cost_supp_A
* 0.27)

                else:

                    discount_by_final_supplier_A = 0

                #print("Discount of Supplier A for Total Demand = ",
discount_by_final_supplier_A)

            else:

                print("No Discount by Supplier A")



            if material_cost_supp_B>0:

                if (5 * 10 * 200 * 1.25) <= material_cost_supp_B < (5 *
20 * 200 * 1.25):

                    discount_by_final_supplier_B =
(material_cost_supp_B*0.06)

                elif (5 * 20 * 200 * 1.25) <= material_cost_supp_B < (5 *
40 * 200 * 1.25):

                    discount_by_final_supplier_B =
(material_cost_supp_B*0.11)

                elif (5 * 40 * 200 * 1.25) <= material_cost_supp_B < (5 *
70 * 200 * 1.25):
```

```
            discount_by_final_supplier_B= (material_cost_supp_B
* 0.16)

        elif (5 * 70 * 200 * 1.25) <= material_cost_supp_B < (5 *
110 * 200 * 1.25):

            discount_by_final_supplier_B= (material_cost_supp_B
* 0.21)

        elif (5 * 110 * 200 * 1.25) <= material_cost_supp_B < (5
* 160 * 200 * 1.25):

            discount_by_final_supplier_B= (material_cost_supp_B
* 0.25)

        elif material_cost_supp_B >= (5 * 160 * 200 * 1.25):

            discount_by_final_supplier_B = (material_cost_supp_B
* 0.28)

        else:

            discount_by_final_supplier_B = 0

        #print("Discount of Supplier B for Total Demand = ",
discount_by_final_supplier_B)

    else:

        print("No Discount by Supplier B")



    if material_cost_supp_C>0:

        if (5 * 10 * 200 * 1.1) <= material_cost_supp_C < (5 * 20
* 200 * 1.1):

            discount_by_final_supplier_C =
(material_cost_supp_C*0.07)

        elif (5 * 20 * 200 * 1.1) <= material_cost_supp_C < (5 *
40 * 200 * 1.1):

            discount_by_final_supplier_C =
(material_cost_supp_C*0.12)

        elif (5 * 40 * 200 * 1.1) <= material_cost_supp_C < (5 *
70 * 200 * 1.1):

            discount_by_final_supplier_C = (material_cost_supp_C
* 0.17)

        elif (5 * 70 * 200 * 1.1) <= material_cost_supp_C < (5 *
110 * 200 * 1.1):
```

```
                discount_by_final_supplier_C = (material_cost_supp_C
* 0.23)

            elif (5 * 110 * 200 * 1.1) <= material_cost_supp_C < (5 *
160 * 200 * 1.1):

                discount_by_final_supplier_C = (material_cost_supp_C
* 0.27)

            elif material_cost_supp_C >= (5 * 160 * 200 * 1.1):

                discount_by_final_supplier_C = (material_cost_supp_C
* 0.3)

            else:

                discount_by_final_supplier_C = 0

            #print("Discount of Supplier C for Total Demand = ",
discount_by_final_supplier_C)

        else:

            print("No Discount by Supplier C")



        if material_cost_supp_P > 0:

            if (5 * 10 * 200 * 1.3) <= material_cost_supp_P < (5 * 20
* 200 * 1.3):

                discount_by_final_supplier_P = (material_cost_supp_P
* 0.05)

            elif (5 * 20 * 200 * 1.3) <= material_cost_supp_P < (5 *
40 * 200 * 1.3):

                discount_by_final_supplier_P = (material_cost_supp_P
* 0.105)

            elif (5 * 40 * 200 * 1.3) <= material_cost_supp_P < (5 *
70 * 200 * 1.3):

                discount_by_final_supplier_P = (material_cost_supp_P
* 0.155)

            elif (5 * 70 * 200 * 1.3) <= material_cost_supp_P < (5 *
110 * 200 * 1.3):

                discount_by_final_supplier_P = (material_cost_supp_P
* 0.205)

            elif (5 * 110 * 200 * 1.3) <= material_cost_supp_P < (5 *
160 * 200 * 1.3):
```

```
            discount_by_final_supplier_P = (material_cost_supp_P
* 0.245)
          elif material_cost_supp_P >= (5 * 160 * 200 * 1.3):
            discount_by_final_supplier_P = (material_cost_supp_P
* 0.275)
          else:
            discount_by_final_supplier_P = 0
          #print("Discount of Supplier P for Order Quantity = ",
discount_by_final_supplier_P)
        else:
          print("No Discount by Supplier P")


        if material_cost_supp_Q > 0:
          if (5 * 10 * 200 * 1.35) <= material_cost_supp_Q < (5 *
20 * 200 * 1.35):
            discount_by_final_supplier_Q = (material_cost_supp_Q
* 0.06)
          elif (5 * 20 * 200 * 1.35) <= material_cost_supp_Q < (5 *
40 * 200 * 1.35):
            discount_by_final_supplier_Q = (material_cost_supp_Q
* 0.115)
          elif (5 * 40 * 200 * 1.35) <= material_cost_supp_Q < (5 *
70 * 200 * 1.35):
            discount_by_final_supplier_Q = (material_cost_supp_Q
* 0.165)
          elif (5 * 70 * 200 * 1.35) <= material_cost_supp_Q < (5 *
110 * 200 * 1.35):
            discount_by_final_supplier_Q = (material_cost_supp_Q
* 0.215)
          elif (5 * 110 * 200 * 1.35) <= material_cost_supp_Q < (5
* 160 * 200 * 1.35):
            discount_by_final_supplier_Q = (material_cost_supp_Q
* 0.255)
          elif material_cost_supp_Q >= (5 * 160 * 200 * 1.35):
```

```
            discount_by_final_supplier_Q = (material_cost_supp_Q
* 0.285)

        else:

            discount_by_final_supplier_Q = 0

        #print("Discount of Supplier Q for Order Quantity = ",
discount_by_final_supplier_Q)

    else:

        print("No Discount by Supplier Q")



    if material_cost_supp_R > 0:

        if (5 * 10 * 200 * 1.1) <= material_cost_supp_R < (5 * 20
* 200 * 1.1):

            discount_by_final_supplier_R = (material_cost_supp_R
* 0.07)

        elif (5 * 20 * 200 * 1.1) <= material_cost_supp_R < (5 *
48 * 200 * 1.1):

            discount_by_final_supplier_R = (material_cost_supp_R
* 0.125)

        elif (5 * 40 * 200 * 1.1) <= material_cost_supp_R < (5 *
70 * 200 * 1.1):

            discount_by_final_supplier_R = (material_cost_supp_R
* 0.175)

        elif (5 * 70 * 200 * 1.35) <= material_cost_supp_R < (5 *
110 * 200 * 1.35):

            discount_by_final_supplier_Q = (material_cost_supp_R
* 0.235)

        elif (5 * 110 * 200 * 1.35) <= material_cost_supp_R < (5
* 160 * 200 * 1.35):

            discount_by_final_supplier_Q = (material_cost_supp_R
* 0.275)

        elif material_cost_supp_R >= (5 * 160 * 200 * 1.1):

            discount_by_final_supplier_R = (material_cost_supp_R
* 0.305)

        else:

            discount_by_final_supplier_R = 0
```

```
            #print("Discount of Supplier R for Order Quantity = ",
discount_by_final_supplier_R)

        else:

            print("No Discount by Supplier R")


#ALL THE CALCULATION DONE FOR INDUSTRY IS SAME
FOR CO-INDUSTRY

        Total_material_cost_final_A = (material_cost_supp_A +
Transportation_cost_A - discount_by_final_supplier_A)

        Total_material_cost_final_B = (material_cost_supp_B +
Transportation_cost_B - discount_by_final_supplier_B)

        Total_material_cost_final_C = (material_cost_supp_C +
Transportation_cost_C - discount_by_final_supplier_C)

        Total_material_cost_final_P = (material_cost_supp_P +
Transportation_cost_P - discount_by_final_supplier_P)

        Total_material_cost_final_Q = (material_cost_supp_Q +
Transportation_cost_Q - discount_by_final_supplier_Q)

        Total_material_cost_final_R = (material_cost_supp_R +
Transportation_cost_R - discount_by_final_supplier_R)


        #QUALITY FACTOR FOR SUPPLIER

        quality_of_supp_A = random.uniform(.93,.9)

        quality_of_supp_B = random.uniform(.98,.94)

        quality_of_supp_C = random.uniform(.93,.88)

        quality_of_supp_P = random.uniform(.92,.9)

        quality_of_supp_Q = random.uniform(.98,.92)

        quality_of_supp_R = random.uniform(.95,.88)


#DEFECT CONSIDERATION

        defective_rate_A = (1-quality_of_supp_A)

        defective_rate_B = (1-quality_of_supp_B)

        defective_rate_C = (1-quality_of_supp_C)

        defective_rate_P = (1-quality_of_supp_P)
```

defective_rate_Q = (1-quality_of_supp_Q)

defective_rate_R = (1-quality_of_supp_R)

no_products_to_extra_manf_A = math.ceil(total_demand * defective_rate_A)

no_products_to_extra_manf_B = math.ceil(total_demand * defective_rate_B)

no_products_to_extra_manf_C = math.ceil(total_demand * defective_rate_C)

print("Number of Products to extra Manufactur choosing Supplier A = ",no_products_to_extra_manf_A)

print("Number of Products to extra Manufactur choosing Supplier B = ",no_products_to_extra_manf_B)

print("Number of Products to extra Manufactur choosing Supplier C = ",no_products_to_extra_manf_C)

no_products_to_extra_manf_P = math.ceil(total_demand * defective_rate_P)

no_products_to_extra_manf_Q = math.ceil(total_demand * defective_rate_Q)

no_products_to_extra_manf_R = math.ceil(total_demand * defective_rate_R)

print("Number of Products to extra Manufactur choosing Supplier P = ",no_products_to_extra_manf_P)

print("Number of Products to extra Manufactur choosing Supplier Q = ",no_products_to_extra_manf_Q)

print("Number of Products to extra Manufactur choosing Supplier R = ",no_products_to_extra_manf_R)

#LEADTIME OF SUPPLIERS FOR CO-INDUSTRY

lead_time_supplier_A = 0

lead_time_supplier_B = 0

lead_time_supplier_C = 0

lead_time_supplier_P = 0

lead_time_supplier_Q = 0

lead_time_supplier_R = 0

```
if 1 <= total_demand <= 100:
    lead_time_supplier_A = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_A = 5
elif 251<= total_demand <= 450:
    lead_time_supplier_A = 6
elif 451<= total_demand <= 700:
    lead_time_supplier_A = 8
elif 701<= total_demand <= 1000:
    lead_time_supplier_A = 10
elif total_demand >= 1001:
    lead_time_supplier_A = 11
else:
    lead_time_supplier_A = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_B = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_B = 5
elif 251<= total_demand <= 450:
    lead_time_supplier_B = 7
elif 451<= total_demand <= 700:
    lead_time_supplier_B = 9
elif 701<= total_demand <= 1000:
    lead_time_supplier_B = 10
elif total_demand >= 1001:
    lead_time_supplier_B = 12
else:
```

```
    lead_time_supplier_B = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_C = 4
elif 101<= total_demand <= 250:
    lead_time_supplier_C = 5
elif 251<= total_demand < 450:
    lead_time_supplier_C = 8
elif 451<= total_demand <= 700:
    lead_time_supplier_C = 10
elif 701<= total_demand <= 1000:
    lead_time_supplier_C = 11
elif total_demand >= 1001:
    lead_time_supplier_C = 13
else:
    lead_time_supplier_C = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_P = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_P = 5
elif 251<= total_demand <= 450:
    lead_time_supplier_P = 7
elif 451<= total_demand <= 700:
    lead_time_supplier_P = 9
elif 701<= total_demand <= 1000:
    lead_time_supplier_P = 10
elif total_demand >= 1001:
    lead_time_supplier_P = 12
```

```
else:
    lead_time_supplier_P = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_Q = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_Q = 4
elif 251<= total_demand <= 450:
    lead_time_supplier_Q = 7
elif 451<= total_demand <= 700:
    lead_time_supplier_Q = 9
elif 701<= total_demand <= 1000:
    lead_time_supplier_Q = 12
elif total_demand >= 1001:
    lead_time_supplier_Q = 14
else:
    lead_time_supplier_Q = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_R = 4
elif 101<= total_demand <= 250:
    lead_time_supplier_R = 5
elif 251<= total_demand < 450:
    lead_time_supplier_R = 8
elif 451<= total_demand <= 700:
    lead_time_supplier_R = 10
elif 701<= total_demand <= 1000:
    lead_time_supplier_R = 12
elif total_demand >= 1001:
```

```
        lead_time_supplier_R = 15
    else:
        lead_time_supplier_R = 0


    #TOTAL COST REQUIRED TO MANUFACTURED FOR CO-INDUSTRY FOR ALL SUPPLIER MATERIAL
    processing_cost = 35
    overhead_cost = 35
    labour_cost = 30
    material_and_trans_cost_A = (Total_material_cost_final_A/qty)
    product_cost_A = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_A)
    total_cost_for_A = Total_material_cost_final_A + (no_products_to_extra_manf_A * material_and_trans_cost_A) + (no_products_to_extra_manf_A * product_cost_A)
    material_and_trans_cost_B = (Total_material_cost_final_B/qty)
    product_cost_B = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_B)
    total_cost_for_B = Total_material_cost_final_B + (no_products_to_extra_manf_B * material_and_trans_cost_B) + (no_products_to_extra_manf_B * product_cost_B)
    material_and_trans_cost_C = (Total_material_cost_final_C/qty)
    product_cost_C = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_C)
    total_cost_for_C = Total_material_cost_final_C + (no_products_to_extra_manf_C * material_and_trans_cost_C) + (no_products_to_extra_manf_C * product_cost_C)


    print('Total Cost for Supplier A = ',total_cost_for_A)
    print('Total Cost for Supplier B = ',total_cost_for_B)
    print('Total Cost for Supplier C = ',total_cost_for_C)
```

```
material_and_trans_cost_P = (Total_material_cost_final_P/qty)

product_cost_P = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_P)

total_cost_for_P = Total_material_cost_final_P + (no_products_to_extra_manf_P * material_and_trans_cost_P) + (no_products_to_extra_manf_P * product_cost_P)


material_and_trans_cost_Q = (Total_material_cost_final_Q/qty)

product_cost_Q = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_Q)

total_cost_for_Q = Total_material_cost_final_Q + (no_products_to_extra_manf_Q * material_and_trans_cost_Q) + (no_products_to_extra_manf_Q * product_cost_Q)


material_and_trans_cost_R = (Total_material_cost_final_R/qty)

product_cost_R = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_R)

total_cost_for_R = Total_material_cost_final_R + (no_products_to_extra_manf_R * material_and_trans_cost_R) + (no_products_to_extra_manf_R * product_cost_R)


print('Total Cost for Supplier P = ',total_cost_for_P)

print('Total Cost for Supplier Q = ',total_cost_for_Q)

print('Total Cost for Supplier R = ',total_cost_for_R)


# WEIGHATGE CALCULATION BY CONSIDERING LEAD TIME FOR CO-INDUSTRY BY

wt_lead_time_a = .3

wt_lead_time_b = .3

wt_lead_time_c = .3
```

```
        if(lead_time_supplier_A < lead_time_supplier_B) and
(lead_time_supplier_A < lead_time_supplier_C):

            #print("Supplier A has min lead time")


            wt_lead_time_b = (.3 - (0.3*((lead_time_supplier_B -
lead_time_supplier_A)/lead_time_supplier_B )))

            wt_lead_time_c = (.3 - (0.3*((lead_time_supplier_C -
lead_time_supplier_A)/lead_time_supplier_C )))

        elif(lead_time_supplier_B < lead_time_supplier_A) and
(lead_time_supplier_B < lead_time_supplier_C):

            #print("Supplier B has min lead time")


            wt_lead_time_a = (.3 - (0.3*((lead_time_supplier_A -
lead_time_supplier_B)/lead_time_supplier_A )))

            wt_lead_time_c = (.3 - (0.3*((lead_time_supplier_C -
lead_time_supplier_B)/lead_time_supplier_C )))

        elif(lead_time_supplier_C < lead_time_supplier_A) and
(lead_time_supplier_C < lead_time_supplier_B):

            #print("Supplier C has min lead time")


            wt_lead_time_a = (.3 - (0.3 * ((lead_time_supplier_A -
lead_time_supplier_C) / lead_time_supplier_A)))

            wt_lead_time_b = (.3 - (0.3 * ((lead_time_supplier_B -
lead_time_supplier_C) / lead_time_supplier_B)))

        #print("Minimum Lead time =
",(min(lead_time_supplier_A,lead_time_supplier_B,lead_time_supplie
r_C)))


        wt_lead_time_p = .3

        wt_lead_time_q = .3

        wt_lead_time_r = .3


        if(lead_time_supplier_P < lead_time_supplier_Q) and
(material_cost_supp_P < lead_time_supplier_R):
```

```
#print("Supplier A has min lead time")


wt_lead_time_q = (.3 - (0.3*((material_cost_supp_Q - material_cost_supp_P)/material_cost_supp_Q )))

wt_lead_time_r = (.3 - (0.3*((material_cost_supp_R - material_cost_supp_P)/material_cost_supp_R )))

elif(material_cost_supp_Q < material_cost_supp_P) and (material_cost_supp_Q < material_cost_supp_R):

#print("Supplier B has min lead time")


wt_lead_time_p = (.3 - (0.3*((material_cost_supp_P - material_cost_supp_Q)/material_cost_supp_P )))

wt_lead_time_r = (.3 - (0.3*((material_cost_supp_R - material_cost_supp_Q)/material_cost_supp_R )))

elif(material_cost_supp_R < material_cost_supp_P) and (material_cost_supp_R < material_cost_supp_Q):

#print("Supplier C has min lead time")


wt_lead_time_p = (.3 - (0.3 * ((material_cost_supp_P - material_cost_supp_R) / material_cost_supp_P)))

wt_lead_time_q = (.3 - (0.3 * ((material_cost_supp_Q - material_cost_supp_R) / material_cost_supp_Q)))

#print("Minimum Lead time = ",(min(material_cost_supp_P,material_cost_supp_Q,material_cost_supp_R)))


# WEIGHATGE CALCUALTION BY CONSIDERING MATERIAL COST FOR CO-INDUSTRY BY

wt_material_cost_a = .7

wt_material_cost_b = .7

wt_material_cost_c = .7


if(total_cost_for_A < total_cost_for_B) and (total_cost_for_A < total_cost_for_C):
```

```
            #print("Supplier A has min total material cost for Initial
Demand")


            wt_material_cost_b = (.7 - (0.7*((total_cost_for_B -
total_cost_for_A)/total_cost_for_A )))

            wt_material_cost_c = (.7 - (0.7*((total_cost_for_C -
total_cost_for_A)/total_cost_for_A )))

        elif(total_cost_for_B < total_cost_for_C) and
(total_cost_for_B < total_cost_for_A):

            #print("Supplier B has min total material cost for Initial
Demand")


            wt_material_cost_a = (.7 - (0.7 * ((total_cost_for_A -
total_cost_for_B) / total_cost_for_B)))

            wt_material_cost_c = (.7 - (0.7 * ((total_cost_for_C -
total_cost_for_B) / total_cost_for_B)))

        elif(total_cost_for_C < total_cost_for_A) and
(total_cost_for_C < total_cost_for_B):

            #print("Supplier C has min total material cost for Initial
Demand")


            wt_material_cost_a = (.7 - (0.7 * ((total_cost_for_A -
total_cost_for_C) / total_cost_for_C)))

            wt_material_cost_b = (.7 - (0.7 * ((total_cost_for_B -
total_cost_for_C) / total_cost_for_C)))


        wt_material_cost_p = .7

        wt_material_cost_q = .7

        wt_material_cost_r = .7


        if(total_cost_for_P < total_cost_for_Q) and
(total_cost_for_P < total_cost_for_R):

            #print("Supplier P has min total material cost for Initial
Demand")
```

```
            wt_material_cost_q = (.7 - (0.7*((total_cost_for_Q -
total_cost_for_P)/total_cost_for_P )))

            wt_material_cost_r = (.7 - (0.7*((total_cost_for_R -
total_cost_for_P)/total_cost_for_P )))

        elif(total_cost_for_Q < total_cost_for_R) and
(total_cost_for_Q < total_cost_for_P):

            #print("Supplier Q has min total material cost for Initial
Demand")


            wt_material_cost_p = (.7 - (0.7 * ((total_cost_for_P -
total_cost_for_Q) / total_cost_for_Q)))

            wt_material_cost_r = (.7 - (0.7 * ((total_cost_for_R -
total_cost_for_Q) / total_cost_for_Q)))

        elif(total_cost_for_R < total_cost_for_P) and
(total_cost_for_R < total_cost_for_Q):

            #print("Supplier R has min total material cost for Initial
Demand")


            wt_material_cost_p = (.7 - (0.7 * ((total_cost_for_P -
total_cost_for_R) / total_cost_for_R)))

            wt_material_cost_q = (.7 - (0.7 * ((total_cost_for_Q -
total_cost_for_R) / total_cost_for_R)))


        supplier_A = ((wt_material_cost_a + wt_lead_time_a) *
100)

        #print("Supplier A weightage = " , supplier_A , "%")

        supplier_B = ((wt_material_cost_b + wt_lead_time_b) *
100)

        #print("Supplier B weightage = " , supplier_B , "%")

        supplier_C = ((wt_material_cost_c + wt_lead_time_c) * 100)

        #print("Supplier C weightage = " , supplier_C , "%")

        supplier_P = ((wt_material_cost_p + wt_lead_time_p) * 100)

        #print("Supplier C weightage = " , supplier_C , "%")

        supplier_Q = ((wt_material_cost_q + wt_lead_time_q) *
100)
```

```
        #print("Supplier C weightage = " , supplier_C , "%")

        supplier_R = ((wt_material_cost_r + wt_lead_time_r) * 100)

        #print("Supplier C weightage = " , supplier_C , "%")



        if(supplier_A > supplier_B) and (supplier_A > supplier_C)
and (supplier_A > supplier_P) and (supplier_A > supplier_Q) and
(supplier_A > supplier_R):

            print("Supplier A is the best...!!!")

            #price = total_cost_for_A

        elif(supplier_B > supplier_A) and (supplier_B > supplier_C)
and (supplier_B > supplier_P) and (supplier_B > supplier_Q) and
(supplier_B > supplier_R):

            print("Supplier B is the best...!!!")

            #price = total_cost_for_B

        elif(supplier_C > supplier_A) and (supplier_C > supplier_B)
and (supplier_C > supplier_P) and (supplier_C > supplier_Q) and
(supplier_C > supplier_R):

            print("Supplier C is the best...!!!")

            #price = total_cost_for_C

        elif(supplier_P > supplier_A) and (supplier_P > supplier_B)
and (supplier_P > supplier_C) and (supplier_P > supplier_Q) and
(supplier_P > supplier_R):

            print("Supplier P is the best...!!!")

            #price = total_cost_for_P

        elif(supplier_Q > supplier_A) and (supplier_Q > supplier_B)
and (supplier_Q > supplier_C) and (supplier_Q > supplier_P) and
(supplier_Q > supplier_R):

            print("Supplier Q is the best...!!!")

            #price = total_cost_for_Q

        elif(supplier_R > supplier_A) and (supplier_R > supplier_B)
and (supplier_R > supplier_C) and (supplier_R > supplier_Q) and
(supplier_R > supplier_P):

            print("Supplier R is the best...!!!")

            #price = total_cost_for_R
```

```
supp_weight_co_ind = (supplier_A,supplier_B,supplier_C,supplier_P,supplier_Q,supplier_R)

cost_co_ind = (Total_material_cost_final_A,Total_material_cost_final_B,Total_material_cost_final_C,Total_material_cost_final_P,Total_material_cost_final_Q,Total_material_cost_final_R)

best_supp_co_ind = max(supplier_A,supplier_B,supplier_C,supplier_P,supplier_Q,supplier_R)

#print ("Best Supplier Weightage for Co-Industry = ",best_supp_co_ind)

index_of_best_supplier_for_coind = supp_weight_co_ind.index(best_supp_co_ind)

material_cost_of_best_supplier_for_coind = cost_co_ind[int(index_of_best_supplier_for_coind)]

#print('Material Cost of Best Supplier of Co-Industry = ',material_cost_of_best_supplier_for_coind)


# COST CALCULATION FOR ALL CO-INDUSTRY TO SELECT THE BEST ONE

# INDUSTRY X

processing_cost_x = 22

overhead_cost_x = 30

labour_cost_x = 20

material_and_trans_cost_x = (material_cost_of_best_supplier_for_coind/qty)

product_cost_x = (processing_cost_x + overhead_cost_x + labour_cost_x + material_and_trans_cost_x)

product_price_x = (product_cost_x * 1.3)

product_price_of_total_demand_x = (qty * product_price_x)


# INDUSTRY Y

processing_cost_y = 25

overhead_cost_y = 32

labour_cost_y = 25
```

```
        material_and_trans_cost_y = (material_cost_of_best_supplier_for_coind/qty)

        product_cost_y = (processing_cost_y + overhead_cost_y + labour_cost_y + material_and_trans_cost_y)

        product_price_y = (product_cost_y * 1.3)

        product_price_of_total_demand_y = (qty * product_price_y)


        # INDUSTRY Z

        processing_cost_z = 23

        overhead_cost_z = 35

        labour_cost_z = 27

        material_and_trans_cost_z = (material_cost_of_best_supplier_for_coind/qty)

        product_cost_z = (processing_cost_z + overhead_cost_z + labour_cost_z + material_and_trans_cost_z)

        product_price_z = (product_cost_z * 1.3)

        product_price_of_total_demand_z = (qty * product_price_z)


        # DISCOUNT OFFER BY CO-INDUSTRY ON OUT SOURCING QUANTITY

        if product_price_of_total_demand_x>0:

          if (30 * product_price_x) <= product_price_of_total_demand_x < (80 * product_price_x):

            discount_by_industry_x = (product_price_of_total_demand_x*0.05)

          elif (80 * product_price_x) <= product_price_of_total_demand_x < (200 * product_price_x):

            discount_by_industry_x = (product_price_of_total_demand_x*0.07)

          elif (200 * product_price_x) <= product_price_of_total_demand_x < (320 * product_price_x):

            discount_by_industry_x = (product_price_of_total_demand_x * 0.1)
```

```
            elif (320 * product_price_x) <=
product_price_of_total_demand_x < (450 * product_price_x):

                discount_by_industry_x =
(product_price_of_total_demand_x * 0.12)

            elif (450 * product_price_x) <=
product_price_of_total_demand_x < (600 * product_price_x):

                discount_by_industry_x =
(product_price_of_total_demand_x * 0.15)

            elif product_price_of_total_demand_x >= (600 *
product_price_x):

                discount_by_industry_x =
(product_price_of_total_demand_x*0.20)

            else:

                discount_by_industry_x = 0

            #print("Discount by Industry X = ",
discount_by_industry_x)

        else:

            print("Discount given by Co-Industry X")



        if product_price_of_total_demand_y>0:

            if (30 * product_price_y) <=
product_price_of_total_demand_y < (80 * product_price_y):

                discount_by_industry_y =
(product_price_of_total_demand_y*0.06)

            elif (80 * product_price_y) <=
product_price_of_total_demand_y < (200 * product_price_y):

                discount_by_industry_y =
(product_price_of_total_demand_y*0.08)

            elif (200 * product_price_y) <=
product_price_of_total_demand_y < (320 * product_price_y):

                discount_by_industry_y =
(product_price_of_total_demand_y * 0.11)

            elif (320 * product_price_y) <=
product_price_of_total_demand_y < (450 * product_price_y):

                discount_by_industry_y =
(product_price_of_total_demand_y * 0.14)
```

```
            elif (450 * product_price_y) <=
product_price_of_total_demand_y < (600 * product_price_y):

                discount_by_industry_y =
(product_price_of_total_demand_y * 0.17)

            elif product_price_of_total_demand_y >= (600 *
product_price_y):

                discount_by_industry_y =
(product_price_of_total_demand_y * 0.22)

            else:

                discount_by_industry_y = 0

            #print("Discount by Industry Y = ",
discount_by_industry_y)

        else:

            print("Discount given by Co-Industry Y")



        if product_price_of_total_demand_z>0:

            if (30 * product_price_z) <=
product_price_of_total_demand_z < (80 * product_price_z):

                discount_by_industry_z =
(product_price_of_total_demand_z*0.07)

            elif (80 * product_price_z) <=
product_price_of_total_demand_z < (200 * product_price_z):

                discount_by_industry_z =
(product_price_of_total_demand_z*0.09)

            elif (200 * product_price_z) <=
product_price_of_total_demand_z < (320 * product_price_z):

                discount_by_industry_z =
(product_price_of_total_demand_z*0.13)

            elif (320 * product_price_z) <=
product_price_of_total_demand_z < (450 * product_price_z):

                discount_by_industry_z =
(product_price_of_total_demand_z*0.17)

            elif (450 * product_price_z) <=
product_price_of_total_demand_z < (600 * product_price_z):

                discount_by_industry_z =
(product_price_of_total_demand_z*0.20)
```

```
                    elif product_price_of_total_demand_z >= (600 *
product_price_z):

                        discount_by_industry_z =
(product_price_of_total_demand_z*0.25)

                    else:

                        discount_by_industry_z = 0

                    #print("Discount by Industry Z = ",
discount_by_industry_z)

                else:

                    print("Discount given by Co-Industry Z")


#TOATL COST OF OUTSOURCING QUANTITY

                product_price_of_total_demand_ind_x =
product_price_of_total_demand_x - discount_by_industry_x

                product_price_of_total_demand_ind_y =
product_price_of_total_demand_y - discount_by_industry_y

                product_price_of_total_demand_ind_z =
product_price_of_total_demand_z - discount_by_industry_z


                #print ("Cost of Single Product of Industry X =
",product_cost_x)

                #print ("Cost of Single Product of Industry Y =
",product_cost_y)

                #print ("Cost of Single Product of Industry Z =
",product_cost_z)

                #print ("Price of Single Product X = ", product_price_x)

                #print ("Price of Single Product Y = ", product_price_y)

                #print ("Price of Single Product Z = ", product_price_z)

                #print("Price of Total Order given to Co-Industry X =
",product_price_of_total_demand_x)

                #print("Price of Total Order given to Co-Industry Y =
",product_price_of_total_demand_y)

                #print("Price of Total Order given to Co-Industry Z =
",product_price_of_total_demand_z)
```

#print("Price of Total Order after discount given to Co-Industry X = ",product_price_of_total_demand_ind_x)

#print("Price of Total Order after discount given to Co-Industry Y = ",product_price_of_total_demand_ind_y)

#print("Price of Total Order after discount given to Co-Industry Z = ",product_price_of_total_demand_ind_z)

#SEELCTION OF THE BEST CO-INDUSTRY BY CONSIDERING COST AND LEAD TIME

wt_cost_ind_x = .65

wt_cost_ind_y = .65

wt_cost_ind_z = .65

if(product_price_of_total_demand_ind_x < product_price_of_total_demand_ind_y) and (product_price_of_total_demand_ind_x < product_price_of_total_demand_ind_z):

#print("Industry X has Best Cost")

wt_cost_ind_y = (.65 - (0.65*((product_price_of_total_demand_ind_y - product_price_of_total_demand_ind_x)/product_price_of_total_demand_ind_y)))

wt_cost_ind_z = (.65 - (0.65*((product_price_of_total_demand_ind_z - product_price_of_total_demand_ind_x)/product_price_of_total_demand_ind_z)))

elif(product_price_of_total_demand_ind_y < product_price_of_total_demand_ind_x) and (product_price_of_total_demand_ind_y < product_price_of_total_demand_ind_z):

#print("Industry Y has Best Cost")

wt_cost_ind_x = (.65 - (0.65*((product_price_of_total_demand_ind_x - product_price_of_total_demand_ind_y)/product_price_of_total_demand_ind_x)))

```
        wt_cost_ind_z = (.65 -
(0.65*((product_price_of_total_demand_ind_z -
product_price_of_total_demand_ind_y)/product_price_of_total_deman
d_ind_z)))

      elif(product_price_of_total_demand_ind_z <
product_price_of_total_demand_ind_x) and
(product_price_of_total_demand_ind_z <
product_price_of_total_demand_ind_y):

        #print("Industry Z has Best Cost")

        wt_cost_ind_x = (.65 - (0.65 *
((product_price_of_total_demand_ind_x -
product_price_of_total_demand_ind_z) /
product_price_of_total_demand_ind_x)))

        wt_cost_ind_y = (.65 - (0.65 *
((product_price_of_total_demand_ind_y -
product_price_of_total_demand_ind_z) /
product_price_of_total_demand_ind_y)))

      #print("Lowest Cost for Total Order =
",(min(product_price_of_total_demand_ind_x,
product_price_of_total_demand_ind_y,
product_price_of_total_demand_ind_z)))

      #print("Wt to Cost of Industry X = ",wt_cost_ind_x)

      #print("Wt to Cost of Industry Y = ",wt_cost_ind_y)

      #print("Wt to Cost of Industry Z = ",wt_cost_ind_z)


      # LEAD TIME

      lead_time_X = 0

      lead_time_Y = 0

      lead_time_Z = 0


      if 1 <= qty <= 100:

        lead_time_X = 4

      elif 101<= qty <= 220:

        lead_time_X = 7

      elif 220<= qty <= 350:

        lead_time_X = 13
```

```
elif 351<= qty <= 500:
    lead_time_X = 17
elif 501<= qty <= 710:
    lead_time_X = 22
elif qty >= 711:
    lead_time_X = 25
else:
    lead_time_X = 0

if 1 <= qty <= 100:
    lead_time_Y = 5
elif 101<= qty <= 220:
    lead_time_Y = 7
elif 221<= qty <= 350:
    lead_time_Y = 12
elif 371<= qty <= 500:
    lead_time_Y = 16
elif 501<= qty <= 710:
    lead_time_Y = 23
elif qty >= 711:
    lead_time_Y = 26
else:
    lead_time_Y = 0

if 1 <= qty <= 100:
    lead_time_Z = 3
elif 111<= qty <= 250:
    lead_time_Z = 8
elif 251<= qty < 350:
```

```
            lead_time_Z = 13
        elif 351<= qty <= 500:
            lead_time_Z = 17
        elif 710<= qty <= 710:
            lead_time_Z = 24
        elif qty >= 711:
            lead_time_Z = 25
        else:
            lead_time_Z = 0

        wt_lead_time_x = .35
        wt_lead_time_y = .35
        wt_lead_time_z = .35

        if(lead_time_X < lead_time_Y) and (lead_time_X <
lead_time_Z):
            #print("Industry X has min lead time")


            wt_lead_time_y = (.35 - (0.35*((lead_time_Y -
lead_time_X)/lead_time_Y)))
            wt_lead_time_z = (.35 - (0.35*((lead_time_Z -
lead_time_X)/lead_time_Z )))
        elif(lead_time_Y < lead_time_X) and (lead_time_Y <
lead_time_Z):
            #print("Industry Y has min lead time")


            wt_lead_time_x = (.35 - (0.35*((lead_time_X -
lead_time_Y)/lead_time_X )))
            wt_lead_time_z = (.35 - (0.35*((lead_time_Z -
lead_time_Y)/lead_time_Z )))
        elif(lead_time_Z < lead_time_X) and (lead_time_Z <
lead_time_Y):
```

```
                #print("Industry Z has min lead time")


                wt_lead_time_x = (.35 - (0.35 * ((lead_time_X -
lead_time_Z) / lead_time_X)))

                wt_lead_time_y = (.35 - (0.35 * ((lead_time_Y -
lead_time_Z) / lead_time_Y)))

            #print("Minimum Lead time =
",(min(lead_time_X,lead_time_Y,lead_time_Z)))

            #print("Wt to Lead Time of X = ",wt_lead_time_x)

            #print("Wt to Lead Time of Y = ",wt_lead_time_y)

            #print("Wt to Lead Time of Z = ",wt_lead_time_z)


            # BEST CO-INDUSTRY SELECTION (IF INITIAL
GENERATED DEMAND IS MORE THAN THE AVAILABLE
CAPACITY OF INDUSTRY)

            industry_X = ((wt_cost_ind_x + wt_lead_time_x) * 100)

            #print("Co-Industry X Total Weightage = " , industry_X,
"%")

            industry_Y = ((wt_cost_ind_y + wt_lead_time_y) * 100)

            #print("Co-Industry Y Total Weightage = " , industry_Y,
"%")

            industry_Z = ((wt_cost_ind_z + wt_lead_time_z) * 100)

            #print("Co-Industry Z Total Weightage = " , industry_Z,
"%")


            if (industry_X > industry_Y) and (industry_X > industry_Z):

                print("Co-Industry X is the best for Given Order...!!!")

            elif (industry_Y > industry_X) and (industry_Y >
industry_Z):

                print("Co-Industry Y is the best for Given Order...!!!")

            elif (industry_Z > industry_X) and (industry_Z >
industry_Y):

                print("Co-Industry Z is the best for Given Order...!!!")
```

```
        ind_weight = (industry_X,industry_Y,industry_Z)

        cost_ind =
(product_price_of_total_demand_ind_x,product_price_of_total_deman
d_ind_y,product_price_of_total_demand_ind_z)

        lead_time_ind = (lead_time_X,lead_time_Y,lead_time_Z)

        best_ind = max(industry_X,industry_Y,industry_Z)

        #print ("Best Supplier Weightage = ",best_supp)

        index_of_best_ind = ind_weight.index(best_ind)

        lead_time_of_best_ind =
lead_time_ind[int(index_of_best_ind)]

        price_of_best_ind = cost_ind[int(index_of_best_ind)]

        per_product_cost = (price_of_best_ind/qty)

        sheet1.write(iteration, 6, per_product_cost)

        sheet1.write(iteration, 7, lead_time_of_best_ind)


        print('Outsource Quantity = ', qty)

        print('Cost per Piece of Outsource Quantity =
',per_product_cost)

        print('Delivery time of Co-Industry =
',lead_time_of_best_ind)


#BEST CO-INDUSTRY SELECTION (IF INITIAL GENERATED
DEMAND IS LESS THAN THE AVAILABLE CAPACITY OF
INDUSTRY AND AGAIN WE APPROCHED THE CUSTOMER TO
SATISFY THE CAPACITY)

    elif (no_of_days_for_manf > available_schedule_days):

      qty = (total_demand - capacity_of_industry)

      sheet1.write(iteration, 5, qty)


      material_cost_supp_A = initial_demand * 200 * 1.4

      material_cost_supp_B = initial_demand * 200 * 1.25

      material_cost_supp_C = initial_demand * 200 * 1.1
```

```
Transportation_cost_A = initial_demand * .2 * 120

Transportation_cost_B = initial_demand * .2 * 200

Transportation_cost_C = initial_demand * .2 * 320

material_cost_supp_P = qty * 200 * 1.3

material_cost_supp_Q = qty * 200 * 1.35

material_cost_supp_R = qty * 200 * 1.1

Transportation_cost_P = qty * .2 * 150

Transportation_cost_Q = qty * .2 * 230

Transportation_cost_R = qty * .2 * 330


# DISCOUNT OF SUPPLIERS...


if material_cost_supp_A>0:

    if (5 * 10 * 200 * 1.4) <= material_cost_supp_A < (5 * 20 *
200 * 1.4):

        discount_by_final_supplier_A =
(material_cost_supp_A*0.05)

    elif (5 * 20 * 200 * 1.4) <= material_cost_supp_A < (5 * 40
* 200 * 1.4):

        discount_by_final_supplier_A =
(material_cost_supp_A*0.10)

    elif (5 * 40 * 200 * 1.4) <= material_cost_supp_A < (5 * 70
* 200 * 1.4):

        discount_by_final_supplier_A = (material_cost_supp_A *
0.15)

    elif (5 * 70 * 200 * 1.4) <= material_cost_supp_A < (5 * 110
* 200 * 1.4):

        discount_by_final_supplier_A = (material_cost_supp_A *
0.20)

    elif (5 * 110 * 200 * 1.4) <= material_cost_supp_A < (5 *
160 * 200 * 1.4):

        discount_by_final_supplier_A = (material_cost_supp_A *
0.24)
```

```
        elif material_cost_supp_A >= (5 * 160 * 200 * 1.4):
            discount_by_final_supplier_A = (material_cost_supp_A * 0.27)
        else:
            discount_by_final_supplier_A = 0
        #print("Discount of Supplier A for Total Demand = ", discount_by_final_supplier_A)
    else:
        print("No Discount by Supplier A")


    if material_cost_supp_B>0:
        if (5 * 10 * 200 * 1.25) <= material_cost_supp_B < (5 * 20 * 200 * 1.25):
            discount_by_final_supplier_B = (material_cost_supp_B*0.06)
        elif (5 * 20 * 200 * 1.25) <= material_cost_supp_B < (5 * 40 * 200 * 1.25):
            discount_by_final_supplier_B = (material_cost_supp_B*0.11)
        elif (5 * 40 * 200 * 1.25) <= material_cost_supp_B < (5 * 70 * 200 * 1.25):
            discount_by_final_supplier_B= (material_cost_supp_B * 0.16)
        elif (5 * 70 * 200 * 1.25) <= material_cost_supp_B < (5 * 110 * 200 * 1.25):
            discount_by_final_supplier_B= (material_cost_supp_B * 0.21)
        elif (5 * 110 * 200 * 1.25) <= material_cost_supp_B < (5 * 160 * 200 * 1.25):
            discount_by_final_supplier_B= (material_cost_supp_B * 0.25)
        elif material_cost_supp_B >= (5 * 160 * 200 * 1.25):
            discount_by_final_supplier_B = (material_cost_supp_B * 0.28)
        else:
```

```
            discount_by_final_supplier_B = 0
        #print("Discount of Supplier B for Total Demand = ",
discount_by_final_supplier_B)
    else:
        print("No Discount by Supplier B")


    if material_cost_supp_C>0:
        if (5 * 10 * 200 * 1.1) <= material_cost_supp_C < (5 * 20 *
200 * 1.1):
            discount_by_final_supplier_C =
(material_cost_supp_C*0.07)
        elif (5 * 20 * 200 * 1.1) <= material_cost_supp_C < (5 * 40
* 200 * 1.1):
            discount_by_final_supplier_C =
(material_cost_supp_C*0.12)
        elif (5 * 40 * 200 * 1.1) <= material_cost_supp_C < (5 * 70
* 200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.17)
        elif (5 * 70 * 200 * 1.1) <= material_cost_supp_C < (5 * 110
* 200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.23)
        elif (5 * 110 * 200 * 1.1) <= material_cost_supp_C < (5 *
160 * 200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.27)
        elif material_cost_supp_C >= (5 * 160 * 200 * 1.1):
            discount_by_final_supplier_C = (material_cost_supp_C *
0.3)
        else:
            discount_by_final_supplier_C = 0
        #print("Discount of Supplier C for Total Demand = ",
discount_by_final_supplier_C)
    else:
```

```
            print("No Discount by Supplier C")


        if material_cost_supp_P > 0:
            if (5 * 10 * 200 * 1.3) <= material_cost_supp_P < (5 * 20 *
200 * 1.3):
                discount_by_final_supplier_P = (material_cost_supp_P *
0.05)
            elif (5 * 20 * 200 * 1.3) <= material_cost_supp_P < (5 * 40 *
200 * 1.3):
                discount_by_final_supplier_P = (material_cost_supp_P *
0.105)
            elif (5 * 40 * 200 * 1.3) <= material_cost_supp_P < (5 * 70 *
200 * 1.3):
                discount_by_final_supplier_P = (material_cost_supp_P *
0.155)
            elif (5 * 70 * 200 * 1.3) <= material_cost_supp_P < (5 * 110
* 200 * 1.3):
                discount_by_final_supplier_P = (material_cost_supp_P *
0.205)
            elif (5 * 110 * 200 * 1.3) <= material_cost_supp_P < (5 *
160 * 200 * 1.3):
                discount_by_final_supplier_P = (material_cost_supp_P *
0.245)
            elif material_cost_supp_P >= (5 * 160 * 200 * 1.3):
                discount_by_final_supplier_P = (material_cost_supp_P *
0.275)
            else:
                discount_by_final_supplier_P = 0
            #print("Discount of Supplier P for Order Quantity = ",
discount_by_final_supplier_P)
        else:
            print("No Discount by Supplier P")


        if material_cost_supp_Q > 0:
```

```
        if (5 * 10 * 200 * 1.35) <= material_cost_supp_Q < (5 * 20 *
200 * 1.35):

          discount_by_final_supplier_Q = (material_cost_supp_Q *
0.06)

        elif (5 * 20 * 200 * 1.35) <= material_cost_supp_Q < (5 * 40
* 200 * 1.35):

          discount_by_final_supplier_Q = (material_cost_supp_Q *
0.115)

        elif (5 * 40 * 200 * 1.35) <= material_cost_supp_Q < (5 * 70
* 200 * 1.35):

          discount_by_final_supplier_Q = (material_cost_supp_Q *
0.165)

        elif (5 * 70 * 200 * 1.35) <= material_cost_supp_Q < (5 *
110 * 200 * 1.35):

          discount_by_final_supplier_Q = (material_cost_supp_Q *
0.215)

        elif (5 * 110 * 200 * 1.35) <= material_cost_supp_Q < (5 *
160 * 200 * 1.35):

          discount_by_final_supplier_Q = (material_cost_supp_Q *
0.255)

        elif material_cost_supp_Q >= (5 * 160 * 200 * 1.35):

          discount_by_final_supplier_Q = (material_cost_supp_Q *
0.285)

        else:

          discount_by_final_supplier_Q = 0

        #print("Discount of Supplier Q for Order Quantity = ",
discount_by_final_supplier_Q)

      else:

        print("No Discount by Supplier Q")



      if material_cost_supp_R > 0:

        if (5 * 10 * 200 * 1.1) <= material_cost_supp_R < (5 * 20 *
200 * 1.1):

          discount_by_final_supplier_R = (material_cost_supp_R *
0.07)
```

```
            elif (5 * 20 * 200 * 1.1) <= material_cost_supp_R < (5 * 48
* 200 * 1.1):

                discount_by_final_supplier_R = (material_cost_supp_R *
0.125)

            elif (5 * 40 * 200 * 1.1) <= material_cost_supp_R < (5 * 70
* 200 * 1.1):

                discount_by_final_supplier_R = (material_cost_supp_R *
0.175)

            elif (5 * 70 * 200 * 1.35) <= material_cost_supp_R < (5 *
110 * 200 * 1.35):

                discount_by_final_supplier_Q = (material_cost_supp_R *
0.235)

            elif (5 * 110 * 200 * 1.35) <= material_cost_supp_R < (5 *
160 * 200 * 1.35):

                discount_by_final_supplier_Q = (material_cost_supp_R *
0.275)

            elif material_cost_supp_R >= (5 * 160 * 200 * 1.1):

                discount_by_final_supplier_R = (material_cost_supp_R *
0.305)

            else:

                discount_by_final_supplier_R = 0

            #print("Discount of Supplier R for Order Quantity = ",
discount_by_final_supplier_R)

        else:

            print("No Discount by Supplier R")



        Total_material_cost_final_A = (material_cost_supp_A +
Transportation_cost_A - discount_by_final_supplier_A)

        Total_material_cost_final_B = (material_cost_supp_B +
Transportation_cost_B - discount_by_final_supplier_B)

        Total_material_cost_final_C = (material_cost_supp_C +
Transportation_cost_C - discount_by_final_supplier_C)



        Total_material_cost_final_P = (material_cost_supp_P +
Transportation_cost_P - discount_by_final_supplier_P)
```

```
Total_material_cost_final_Q = (material_cost_supp_Q + Transportation_cost_Q - discount_by_final_supplier_Q)

Total_material_cost_final_R = (material_cost_supp_R + Transportation_cost_R - discount_by_final_supplier_R)


#QUALITY OF SUPPLIER


quality_of_supp_A = random.uniform(.93,.9)

quality_of_supp_B = random.uniform(.98,.94)

quality_of_supp_C = random.uniform(.93,.88)


quality_of_supp_P = random.uniform(.92,.9)

quality_of_supp_Q = random.uniform(.98,.92)

quality_of_supp_R = random.uniform(.95,.88)


defective_rate_A = (1-quality_of_supp_A)

defective_rate_B = (1-quality_of_supp_B)

defective_rate_C = (1-quality_of_supp_C)


defective_rate_P = (1-quality_of_supp_P)

defective_rate_Q = (1-quality_of_supp_Q)

defective_rate_R = (1-quality_of_supp_R)


no_products_to_extra_manf_A = math.ceil(total_demand * defective_rate_A)

no_products_to_extra_manf_B = math.ceil(total_demand * defective_rate_B)

no_products_to_extra_manf_C = math.ceil(total_demand * defective_rate_C)

print("Number of Products to extra Manufactur choosing Supplier A = ",no_products_to_extra_manf_A)
```

```
print("Number of Products to extra Manufactur choosing Supplier B = ",no_products_to_extra_manf_B)

print("Number of Products to extra Manufactur choosing Supplier C = ",no_products_to_extra_manf_C)


no_products_to_extra_manf_P = math.ceil(total_demand * defective_rate_P)

no_products_to_extra_manf_Q = math.ceil(total_demand * defective_rate_Q)

no_products_to_extra_manf_R = math.ceil(total_demand * defective_rate_R)

print("Number of Products to extra Manufactur choosing Supplier P = ",no_products_to_extra_manf_P)

print("Number of Products to extra Manufactur choosing Supplier Q = ",no_products_to_extra_manf_Q)

print("Number of Products to extra Manufactur choosing Supplier R = ",no_products_to_extra_manf_R)


#LEAD TIME OF SUPPLIERS

lead_time_supplier_A = 0

lead_time_supplier_B = 0

lead_time_supplier_C = 0


lead_time_supplier_P = 0

lead_time_supplier_Q = 0

lead_time_supplier_R = 0


if 1 <= total_demand <= 100:

   lead_time_supplier_A = 3

elif 101<= total_demand <= 250:

   lead_time_supplier_A = 5

elif 251<= total_demand <= 450:

   lead_time_supplier_A = 6
```

```
elif 451<= total_demand <= 700:
    lead_time_supplier_A = 8
elif 701<= total_demand <= 1000:
    lead_time_supplier_A = 10
elif total_demand >= 1001:
    lead_time_supplier_A = 11
else:
    lead_time_supplier_A = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_B = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_B = 5
elif 251<= total_demand <= 450:
    lead_time_supplier_B = 7
elif 451<= total_demand <= 700:
    lead_time_supplier_B = 9
elif 701<= total_demand <= 1000:
    lead_time_supplier_B = 10
elif total_demand >= 1001:
    lead_time_supplier_B = 12
else:
    lead_time_supplier_B = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_C = 4
elif 101<= total_demand <= 250:
    lead_time_supplier_C = 5
elif 251<= total_demand < 450:
```

```
    lead_time_supplier_C = 8
elif 451<= total_demand <= 700:
    lead_time_supplier_C = 10
elif 701<= total_demand <= 1000:
    lead_time_supplier_C = 11
elif total_demand >= 1001:
    lead_time_supplier_C = 13
else:
    lead_time_supplier_C = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_P = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_P = 5
elif 251<= total_demand <= 450:
    lead_time_supplier_P = 7
elif 451<= total_demand <= 700:
    lead_time_supplier_P = 9
elif 701<= total_demand <= 1000:
    lead_time_supplier_P = 10
elif total_demand >= 1001:
    lead_time_supplier_P = 12
else:
    lead_time_supplier_P = 0

if 1 <= total_demand <= 100:
    lead_time_supplier_Q = 3
elif 101<= total_demand <= 250:
    lead_time_supplier_Q = 4
```

```
    elif 251<= total_demand <= 450:
        lead_time_supplier_Q = 7
    elif 451<= total_demand <= 700:
        lead_time_supplier_Q = 9
    elif 701<= total_demand <= 1000:
        lead_time_supplier_Q = 12
    elif total_demand >= 1001:
        lead_time_supplier_Q = 14
    else:
        lead_time_supplier_Q = 0

    if 1 <= total_demand <= 100:
        lead_time_supplier_R = 4
    elif 101<= total_demand <= 250:
        lead_time_supplier_R = 5
    elif 251<= total_demand < 450:
        lead_time_supplier_R = 8
    elif 451<= total_demand <= 700:
        lead_time_supplier_R = 10
    elif 701<= total_demand <= 1000:
        lead_time_supplier_R = 12
    elif total_demand >= 1001:
        lead_time_supplier_R = 15
    else:
        lead_time_supplier_R = 0

    #TOTAL COST REQUIRED TO MANUFACTURED THE NUMBER OF DEMAND BY USING ALL THE SUPPLIER MATERIAL
    processing_cost = 35
```

```
overhead_cost = 35

labour_cost = 30


material_and_trans_cost_A = (Total_material_cost_final_A/qty)

product_cost_A = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_A)

total_cost_for_A = Total_material_cost_final_A + (no_products_to_extra_manf_A * material_and_trans_cost_A) + (no_products_to_extra_manf_A * product_cost_A)


material_and_trans_cost_B = (Total_material_cost_final_B/qty)

product_cost_B = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_B)

total_cost_for_B = Total_material_cost_final_B + (no_products_to_extra_manf_B * material_and_trans_cost_B) + (no_products_to_extra_manf_B * product_cost_B)


material_and_trans_cost_C = (Total_material_cost_final_C/qty)

product_cost_C = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_C)

total_cost_for_C = Total_material_cost_final_C + (no_products_to_extra_manf_C * material_and_trans_cost_C) + (no_products_to_extra_manf_C * product_cost_C)


#print('Total Cost for Supplier A = ',total_cost_for_A)

#print('Total Cost for Supplier B = ',total_cost_for_B)

#print('Total Cost for Supplier C = ',total_cost_for_C)


material_and_trans_cost_P = (Total_material_cost_final_P/qty)

product_cost_P = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_P)
```

```
	total_cost_for_P = Total_material_cost_final_P + (no_products_to_extra_manf_P * material_and_trans_cost_P) + (no_products_to_extra_manf_P * product_cost_P)


	material_and_trans_cost_Q = (Total_material_cost_final_Q/qty)

	product_cost_Q = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_Q)

	total_cost_for_Q = Total_material_cost_final_Q + (no_products_to_extra_manf_Q * material_and_trans_cost_Q) + (no_products_to_extra_manf_Q * product_cost_Q)


	material_and_trans_cost_R = (Total_material_cost_final_R/qty)

	product_cost_R = (processing_cost + overhead_cost + labour_cost + material_and_trans_cost_R)

	total_cost_for_R = Total_material_cost_final_R + (no_products_to_extra_manf_R * material_and_trans_cost_R) + (no_products_to_extra_manf_R * product_cost_R)


	#print('Total Cost for Supplier P = ',total_cost_for_P)

	#print('Total Cost for Supplier Q = ',total_cost_for_Q)

	#print('Total Cost for Supplier R = ',total_cost_for_R)


	wt_lead_time_a = .3

	wt_lead_time_b = .3

	wt_lead_time_c = .3


	if(lead_time_supplier_A < lead_time_supplier_B) and (lead_time_supplier_A < lead_time_supplier_C):

		#print("Supplier A has min lead time")


		wt_lead_time_b = (.3 - (0.3*((lead_time_supplier_B - lead_time_supplier_A)/lead_time_supplier_B )))
```

```
        wt_lead_time_c = (.3 - (0.3*((lead_time_supplier_C - lead_time_supplier_A)/lead_time_supplier_C )))

    elif(lead_time_supplier_B < lead_time_supplier_A) and (lead_time_supplier_B < lead_time_supplier_C):

        #print("Supplier B has min lead time")


        wt_lead_time_a = (.3 - (0.3*((lead_time_supplier_A - lead_time_supplier_B)/lead_time_supplier_A )))

        wt_lead_time_c = (.3 - (0.3*((lead_time_supplier_C - lead_time_supplier_B)/lead_time_supplier_C )))

    elif(lead_time_supplier_C < lead_time_supplier_A) and (lead_time_supplier_C < lead_time_supplier_B):

        #print("Supplier C has min lead time")


        wt_lead_time_a = (.3 - (0.3 * ((lead_time_supplier_A - lead_time_supplier_C) / lead_time_supplier_A)))

        wt_lead_time_b = (.3 - (0.3 * ((lead_time_supplier_B - lead_time_supplier_C) / lead_time_supplier_B)))

    #print("Minimum Lead time = ",(min(lead_time_supplier_A,lead_time_supplier_B,lead_time_supplier_C)))


    wt_lead_time_p = .3

    wt_lead_time_q = .3

    wt_lead_time_r = .3

    if(lead_time_supplier_P < lead_time_supplier_Q) and (material_cost_supp_P < lead_time_supplier_R):

        #print("Supplier A has min lead time")


        wt_lead_time_q = (.3 - (0.3*((material_cost_supp_Q - material_cost_supp_P)/material_cost_supp_Q )))

        wt_lead_time_r = (.3 - (0.3*((material_cost_supp_R - material_cost_supp_P)/material_cost_supp_R )))

    elif(material_cost_supp_Q < material_cost_supp_P) and (material_cost_supp_Q < material_cost_supp_R):
```

```
            #print("Supplier B has min lead time")


            wt_lead_time_p = (.3 - (0.3*((material_cost_supp_P -
material_cost_supp_Q)/material_cost_supp_P )))

            wt_lead_time_r = (.3 - (0.3*((material_cost_supp_R -
material_cost_supp_Q)/material_cost_supp_R )))

        elif(material_cost_supp_R < material_cost_supp_P) and
(material_cost_supp_R < material_cost_supp_Q):

            #print("Supplier C has min lead time")


            wt_lead_time_p = (.3 - (0.3 * ((material_cost_supp_P -
material_cost_supp_R) / material_cost_supp_P)))

            wt_lead_time_q = (.3 - (0.3 * ((material_cost_supp_Q -
material_cost_supp_R) / material_cost_supp_Q)))

        #print("Minimum Lead time =
",(min(material_cost_supp_P,material_cost_supp_Q,material_cost_sup
p_R)))


        wt_material_cost_a = .7

        wt_material_cost_b = .7

        wt_material_cost_c = .7

        if(total_cost_for_A < total_cost_for_B) and (total_cost_for_A
< total_cost_for_C):

            #print("Supplier A has min total material cost for Initial
Demand")


            wt_material_cost_b = (.7 - (0.7*((total_cost_for_B -
total_cost_for_A)/total_cost_for_A )))

            wt_material_cost_c = (.7 - (0.7*((total_cost_for_C -
total_cost_for_A)/total_cost_for_A )))

        elif(total_cost_for_B < total_cost_for_C) and (total_cost_for_B
< total_cost_for_A):

            #print("Supplier B has min total material cost for Initial
Demand")
```

```
        wt_material_cost_a = (.7 - (0.7 * ((total_cost_for_A - total_cost_for_B) / total_cost_for_B)))

        wt_material_cost_c = (.7 - (0.7 * ((total_cost_for_C - total_cost_for_B) / total_cost_for_B)))

    elif(total_cost_for_C < total_cost_for_A) and (total_cost_for_C < total_cost_for_B):

        #print("Supplier C has min total material cost for Initial Demand")


        wt_material_cost_a = (.7 - (0.7 * ((total_cost_for_A - total_cost_for_C) / total_cost_for_C)))

        wt_material_cost_b = (.7 - (0.7 * ((total_cost_for_B - total_cost_for_C) / total_cost_for_C)))


    wt_material_cost_p = .7

    wt_material_cost_q = .7

    wt_material_cost_r = .7


    if(total_cost_for_P < total_cost_for_Q) and (total_cost_for_P < total_cost_for_R):

        #print("Supplier P has min total material cost for Initial Demand")


        wt_material_cost_q = (.7 - (0.7*((total_cost_for_Q - total_cost_for_P)/total_cost_for_P )))

        wt_material_cost_r = (.7 - (0.7*((total_cost_for_R - total_cost_for_P)/total_cost_for_P )))

    elif(total_cost_for_Q < total_cost_for_R) and (total_cost_for_Q < total_cost_for_P):

        #print("Supplier Q has min total material cost for Initial Demand")


        wt_material_cost_p = (.7 - (0.7 * ((total_cost_for_P - total_cost_for_Q) / total_cost_for_Q)))
```

wt_material_cost_r = (.7 - (0.7 * ((total_cost_for_R - total_cost_for_Q) / total_cost_for_Q)))

elif(total_cost_for_R < total_cost_for_P) and (total_cost_for_R < total_cost_for_Q):

#print("Supplier R has min total material cost for Initial Demand")

wt_material_cost_p = (.7 - (0.7 * ((total_cost_for_P - total_cost_for_R) / total_cost_for_R)))

wt_material_cost_q = (.7 - (0.7 * ((total_cost_for_Q - total_cost_for_R) / total_cost_for_R)))

supplier_A = ((wt_material_cost_a + wt_lead_time_a) * 100)

#print("Supplier A weightage = " , supplier_A , "%")

supplier_B = ((wt_material_cost_b + wt_lead_time_b) * 100)

#print("Supplier B weightage = " , supplier_B , "%")

supplier_C = ((wt_material_cost_c + wt_lead_time_c) * 100)

#print("Supplier C weightage = " , supplier_C , "%")

supplier_P = ((wt_material_cost_p + wt_lead_time_p) * 100)

#print("Supplier C weightage = " , supplier_C , "%")

supplier_Q = ((wt_material_cost_q + wt_lead_time_q) * 100)

#print("Supplier C weightage = " , supplier_C , "%")

supplier_R = ((wt_material_cost_r + wt_lead_time_r) * 100)

#print("Supplier C weightage = " , supplier_C , "%")

if(supplier_A > supplier_B) and (supplier_A > supplier_C) and (supplier_A > supplier_P) and (supplier_A > supplier_Q) and (supplier_A > supplier_R):

print("Supplier A is the best...!!!")

#price = total_cost_for_A

elif(supplier_B > supplier_A) and (supplier_B > supplier_C) and (supplier_B > supplier_P) and (supplier_B > supplier_Q) and (supplier_B > supplier_R):

print("Supplier B is the best...!!!")

#price = total_cost_for_B

elif(supplier_C > supplier_A) and (supplier_C > supplier_B) and (supplier_C > supplier_P) and (supplier_C > supplier_Q) and (supplier_C > supplier_R):

print("Supplier C is the best...!!!")

#price = total_cost_for_C

elif(supplier_P > supplier_A) and (supplier_P > supplier_B) and (supplier_P > supplier_C) and (supplier_P > supplier_Q) and (supplier_P > supplier_R):

print("Supplier P is the best...!!!")

#price = total_cost_for_P

elif(supplier_Q > supplier_A) and (supplier_Q > supplier_B) and (supplier_Q > supplier_C) and (supplier_Q > supplier_P) and (supplier_Q > supplier_R):

print("Supplier Q is the best...!!!")

#price = total_cost_for_Q

elif(supplier_R > supplier_A) and (supplier_R > supplier_B) and (supplier_R > supplier_C) and (supplier_R > supplier_Q) and (supplier_R > supplier_P):

print("Supplier R is the best...!!!")

#price = total_cost_for_R

supp_weight_co_ind = (supplier_A,supplier_B,supplier_C,supplier_P,supplier_Q,supplier_R)

cost_co_ind = (Total_material_cost_final_A,Total_material_cost_final_B,Total_material_cost_final_C,Total_material_cost_final_P,Total_material_cost_final_Q,Total_material_cost_final_R)

best_supp_co_ind = max(supplier_A,supplier_B,supplier_C,supplier_P,supplier_Q,supplier_R)

#print ("Best Supplier Weightage for Co-Industry = ",best_supp_co_ind)

index_of_best_supplier_for_coind = supp_weight_co_ind.index(best_supp_co_ind)

```
material_cost_of_best_supplier_for_coind =
cost_co_ind[int(index_of_best_supplier_for_coind)]

#print('Material Cost of Best Supplier of Co-Industry =
',material_cost_of_best_supplier_for_coind)


# COST CALCULATION OF CO-INDUSTRY

# INDUSTRY X

processing_cost_x = 22

overhead_cost_x = 30

labour_cost_x = 20

material_and_trans_cost_x =
(material_cost_of_best_supplier_for_coind/qty)

product_cost_x = (processing_cost_x + overhead_cost_x +
labour_cost_x + material_and_trans_cost_x)

product_price_x = (product_cost_x * 1.3)

product_price_of_total_demand_x = (qty * product_price_x)


# INDUSTRY Y

processing_cost_y = 25

overhead_cost_y = 32

labour_cost_y = 25

material_and_trans_cost_y =
(material_cost_of_best_supplier_for_coind/qty)

product_cost_y = (processing_cost_y + overhead_cost_y +
labour_cost_y + material_and_trans_cost_y)

product_price_y = (product_cost_y * 1.3)

product_price_of_total_demand_y = (qty * product_price_y)


# INDUSTRY Z

processing_cost_z = 23

overhead_cost_z = 35

labour_cost_z = 27
```

```
material_and_trans_cost_z = (material_cost_of_best_supplier_for_coind/qty)

product_cost_z = (processing_cost_z + overhead_cost_z + labour_cost_z + material_and_trans_cost_z)

product_price_z = (product_cost_z * 1.3)

product_price_of_total_demand_z = (qty * product_price_z)


# DISCOUNT GIVEN BY CO-INDUSTRY ON QUANTITY


if product_price_of_total_demand_x>0:

    if (30 * product_price_x) <= product_price_of_total_demand_x < (80 * product_price_x):

        discount_by_industry_x = (product_price_of_total_demand_x*0.05)

    elif (80 * product_price_x) <= product_price_of_total_demand_x < (200 * product_price_x):

        discount_by_industry_x = (product_price_of_total_demand_x*0.07)

    elif (200 * product_price_x) <= product_price_of_total_demand_x < (320 * product_price_x):

        discount_by_industry_x = (product_price_of_total_demand_x * 0.1)

    elif (320 * product_price_x) <= product_price_of_total_demand_x < (450 * product_price_x):

        discount_by_industry_x = (product_price_of_total_demand_x * 0.12)

    elif (450 * product_price_x) <= product_price_of_total_demand_x < (600 * product_price_x):

        discount_by_industry_x = (product_price_of_total_demand_x * 0.15)

    elif product_price_of_total_demand_x >= (600 * product_price_x):

        discount_by_industry_x = (product_price_of_total_demand_x*0.20)

    else:
```

```
discount_by_industry_x = 0

#print("Discount by Industry X = ", discount_by_industry_x)

else:

print("Discount given by Co-Industry X")



if product_price_of_total_demand_y>0:

if (30 * product_price_y) <=
product_price_of_total_demand_y < (80 * product_price_y):

discount_by_industry_y =
(product_price_of_total_demand_y*0.06)

elif (80 * product_price_y) <=
product_price_of_total_demand_y < (200 * product_price_y):

discount_by_industry_y =
(product_price_of_total_demand_y*0.08)

elif (200 * product_price_y) <=
product_price_of_total_demand_y < (320 * product_price_y):

discount_by_industry_y =
(product_price_of_total_demand_y * 0.11)

elif (320 * product_price_y) <=
product_price_of_total_demand_y < (450 * product_price_y):

discount_by_industry_y =
(product_price_of_total_demand_y * 0.14)

elif (450 * product_price_y) <=
product_price_of_total_demand_y < (600 * product_price_y):

discount_by_industry_y =
(product_price_of_total_demand_y * 0.17)

elif product_price_of_total_demand_y >= (600 *
product_price_y):

discount_by_industry_y =
(product_price_of_total_demand_y * 0.22)

else:

discount_by_industry_y = 0

#print("Discount by Industry Y = ", discount_by_industry_y)

else:
```

```
        print("Discount given by Co-Industry Y")


    if product_price_of_total_demand_z>0:
        if (30 * product_price_z) <=
product_price_of_total_demand_z < (80 * product_price_z):
            discount_by_industry_z =
(product_price_of_total_demand_z*0.07)
        elif (80 * product_price_z) <=
product_price_of_total_demand_z < (200 * product_price_z):
            discount_by_industry_z =
(product_price_of_total_demand_z*0.09)
        elif (200 * product_price_z) <=
product_price_of_total_demand_z < (320 * product_price_z):
            discount_by_industry_z =
(product_price_of_total_demand_z*0.13)
        elif (320 * product_price_z) <=
product_price_of_total_demand_z < (450 * product_price_z):
            discount_by_industry_z =
(product_price_of_total_demand_z*0.17)
        elif (450 * product_price_z) <=
product_price_of_total_demand_z < (600 * product_price_z):
            discount_by_industry_z =
(product_price_of_total_demand_z*0.20)
        elif product_price_of_total_demand_z >= (600 *
product_price_z):
            discount_by_industry_z =
(product_price_of_total_demand_z*0.25)
        else:
            discount_by_industry_z = 0
        #print("Discount by Industry Z = ", discount_by_industry_z)
    else:
        print("Discount given by Co-Industry Z")
    product_price_of_total_demand_ind_x =
product_price_of_total_demand_x - discount_by_industry_x
```

```
product_price_of_total_demand_ind_y =
product_price_of_total_demand_y - discount_by_industry_y

product_price_of_total_demand_ind_z =
product_price_of_total_demand_z - discount_by_industry_z



#print ("Cost of Single Product of Industry X =
",product_cost_x)

#print ("Cost of Single Product of Industry Y =
",product_cost_y)

#print ("Cost of Single Product of Industry Z =
",product_cost_z)

#print ("Price of Single Product X = ", product_price_x)

#print ("Price of Single Product Y = ", product_price_y)

#print ("Price of Single Product Z = ", product_price_z)

#print("Price of Total Order given to Co-Industry X =
",product_price_of_total_demand_x)

#print("Price of Total Order given to Co-Industry Y =
",product_price_of_total_demand_y)

#print("Price of Total Order given to Co-Industry Z =
",product_price_of_total_demand_z)

#print("Price of Total Order after discount given to Co-Industry
X = ",product_price_of_total_demand_ind_x)

#print("Price of Total Order after discount given to Co-Industry
Y = ",product_price_of_total_demand_ind_y)

#print("Price of Total Order after discount given to Co-Industry
Z = ",product_price_of_total_demand_ind_z)



wt_cost_ind_x = .65

wt_cost_ind_y = .65

wt_cost_ind_z = .65



if(product_price_of_total_demand_ind_x <
product_price_of_total_demand_ind_y) and
(product_price_of_total_demand_ind_x <
product_price_of_total_demand_ind_z):
```

```
                #print("Industry X has Best Cost")


                wt_cost_ind_y = (.65 - 
(0.65*((product_price_of_total_demand_ind_y - 
product_price_of_total_demand_ind_x)/product_price_of_total_deman
d_ind_y)))

                wt_cost_ind_z = (.65 - 
(0.65*((product_price_of_total_demand_ind_z - 
product_price_of_total_demand_ind_x)/product_price_of_total_deman
d_ind_z)))

            elif(product_price_of_total_demand_ind_y < 
product_price_of_total_demand_ind_x) and 
(product_price_of_total_demand_ind_y < 
product_price_of_total_demand_ind_z):

                #print("Industry Y has Best Cost")


                wt_cost_ind_x = (.65 - 
(0.65*((product_price_of_total_demand_ind_x - 
product_price_of_total_demand_ind_y)/product_price_of_total_deman
d_ind_x)))

                wt_cost_ind_z = (.65 - 
(0.65*((product_price_of_total_demand_ind_z - 
product_price_of_total_demand_ind_y)/product_price_of_total_deman
d_ind_z)))

            elif(product_price_of_total_demand_ind_z < 
product_price_of_total_demand_ind_x) and 
(product_price_of_total_demand_ind_z < 
product_price_of_total_demand_ind_y):

                #print("Industry Z has Best Cost")

                wt_cost_ind_x = (.65 - (0.65 * 
((product_price_of_total_demand_ind_x - 
product_price_of_total_demand_ind_z) / 
product_price_of_total_demand_ind_x)))

                wt_cost_ind_y = (.65 - (0.65 * 
((product_price_of_total_demand_ind_y - 
product_price_of_total_demand_ind_z) / 
product_price_of_total_demand_ind_y)))

            #print("Lowest Cost for Total Order = 
",(min(product_price_of_total_demand_ind_x, 
product_price_of_total_demand_ind_y, 
product_price_of_total_demand_ind_z)))
```

```
#print("Wt to Cost of Industry X = ",wt_cost_ind_x)
#print("Wt to Cost of Industry Y = ",wt_cost_ind_y)
#print("Wt to Cost of Industry Z = ",wt_cost_ind_z)

# LEAD TIME OF CO-INDUSTRY
lead_time_X = 0
lead_time_Y = 0
lead_time_Z = 0

if 1 <= qty <= 100:
    lead_time_X = 4
elif 101<= qty <= 220:
    lead_time_X = 7
elif 220<= qty <= 350:
    lead_time_X = 13
elif 351<= qty <= 500:
    lead_time_X = 17
elif 501<= qty <= 710:
    lead_time_X = 22
elif qty >= 711:
    lead_time_X = 25
else:
    lead_time_X = 0

if 1 <= qty <= 100:
    lead_time_Y = 5
elif 101<= qty <= 220:
    lead_time_Y = 7
elif 221<= qty <= 350:
```

```
    lead_time_Y = 12
elif 371<= qty <= 500:
    lead_time_Y = 16
elif 501<= qty <= 710:
    lead_time_Y = 23
elif qty >= 711:
    lead_time_Y = 26
else:
    lead_time_Y = 0

if 1 <= qty <= 100:
    lead_time_Z = 3
elif 111<= qty <= 250:
    lead_time_Z = 8
elif 251<= qty < 350:
    lead_time_Z = 13
elif 351<= qty <= 500:
    lead_time_Z = 17
elif 710<= qty <= 710:
    lead_time_Z = 24
elif qty >= 711:
    lead_time_Z = 25
else:
    lead_time_Z = 0

wt_lead_time_x = .35
wt_lead_time_y = .35
wt_lead_time_z = .35
```

```
if(lead_time_X < lead_time_Y) and (lead_time_X <
lead_time_Z):

    #print("Industry X has min lead time")


    wt_lead_time_y = (.35 - (0.35*((lead_time_Y -
lead_time_X)/lead_time_Y)))

    wt_lead_time_z = (.35 - (0.35*((lead_time_Z -
lead_time_X)/lead_time_Z )))

elif(lead_time_Y < lead_time_X) and (lead_time_Y <
lead_time_Z):

    #print("Industry Y has min lead time")


    wt_lead_time_x = (.35 - (0.35*((lead_time_X -
lead_time_Y)/lead_time_X )))

    wt_lead_time_z = (.35 - (0.35*((lead_time_Z -
lead_time_Y)/lead_time_Z )))

elif(lead_time_Z < lead_time_X) and (lead_time_Z <
lead_time_Y):

    #print("Industry Z has min lead time")


    wt_lead_time_x = (.35 - (0.35 * ((lead_time_X -
lead_time_Z) / lead_time_X)))

    wt_lead_time_y = (.35 - (0.35 * ((lead_time_Y -
lead_time_Z) / lead_time_Y)))

#print("Minimum Lead time =
",(min(lead_time_X,lead_time_Y,lead_time_Z)))

#print("Wt to Lead Time of X = ",wt_lead_time_x)

#print("Wt to Lead Time of Y = ",wt_lead_time_y)

#print("Wt to Lead Time of Z = ",wt_lead_time_z)


# BEST CO-INDUSTRY SELECTION

industry_X = ((wt_cost_ind_x + wt_lead_time_x) * 100)

#print("Co-Industry X Total Weightage = " , industry_X, "%")
```

```
industry_Y = ((wt_cost_ind_y + wt_lead_time_y) * 100)
#print("Co-Industry Y Total Weightage = " , industry_Y, "%")
industry_Z = ((wt_cost_ind_z + wt_lead_time_z) * 100)
#print("Co-Industry Z Total Weightage = " , industry_Z, "%")

if (industry_X > industry_Y) and (industry_X > industry_Z):
   print("Co-Industry X is the best for Given Order...!!!")
elif (industry_Y > industry_X) and (industry_Y > industry_Z):
   print("Co-Industry Y is the best for Given Order...!!!")
elif (industry_Z > industry_X) and (industry_Z > industry_Y):
   print("Co-Industry Z is the best for Given Order...!!!")

ind_weight = (industry_X,industry_Y,industry_Z)
cost_ind = (product_price_of_total_demand_ind_x,product_price_of_total_demand_ind_y,product_price_of_total_demand_ind_z)
lead_time_ind = (lead_time_X,lead_time_Y,lead_time_Z)
best_ind = max(industry_X,industry_Y,industry_Z)
#print ("Best Supplier Weightage = ",best_supp)
index_of_best_ind = ind_weight.index(best_ind)
lead_time_of_best_ind = lead_time_ind[int(index_of_best_ind)]
price_of_best_ind = cost_ind[int(index_of_best_ind)]
per_product_cost = (price_of_best_ind/qty)
sheet1.write(iteration, 6, per_product_cost)
sheet1.write(iteration, 7, lead_time_of_best_ind)
print('Outsource Quantity = ', qty)
print('Cost per Piece of Outsource Quantity = ',per_product_cost)
print('Delivery time of Co-Industry = ',lead_time_of_best_ind)
```

```
        #else:
            #print('Total is Less than Capacity of Industry')


wb.save('one.xls')


#cost_fact = int(input('Enter Cost Factor = '))
#if(cost_fact == 1):
one()
```

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