Chapter1

Introduction

OVERVIEW OF BRASS INDUSTRY

This chapter provides an overview of the brass industry, which is the focus of this study. It covers key aspects such as the industry's terminology, basic concepts, history, the types of metals and alloys used, manufacturing methods, and more.

What is Brass?

Brass is a metal alloy made from combining copper and zinc, with small amounts of other elements added for specific purposes.

Alloy

An alloy is a metal made by combining two or more different metals. Alloys are created to enhance a metal's properties, such as increasing strength, reducing weight, improving resistance to corrosion and wear, or changing its color. To make an alloy, one metal is melted and mixed with another. Copper, being widely available, is often used in various alloys. Brass, for instance, is formed by mixing copper and zinc.

❖ Overview

Brass is primarily composed of copper and zinc. It is typically classified as a copper alloy because copper is the dominant element in its composition.[3] The colour of brass depends on the amount of zinc it contains, ranging from dark reddish-brown to bright yellow. The more zinc in the brass, the lighter the colour. Zinc content can vary from 10% to about 45%.

Brass is chosen for its desirable qualities, which include being stronger and harder than copper, easy to mold into various shapes, a good conductor of heat, and resistant to corrosion, especially from saltwater. These properties[5] make brass a preferred material in many fields, including general manufacturing, electrical, and precision engineering. It is also used in creating pipes, tubes, screws, radiators, architectural details, musical instruments, and firearm cartridges. Brass's excellent durability and resistance to wear make it ideal for applications where long-lasting performance is essential.

❖ The History of the Brass Industry

The discovery of metal revolutionized the lives of ancient people. Metal and its alloys, like brass, played a key role in agriculture by providing farmers with more effective tools, and they were also crucial in warfare, where metal weapons like swords, shields, and knives gave armies a significant advantage.

A Global History of the Brass Industry

Our ancestors were the first "geologists" and "miners," learning how to use and shape different rocks for tools, weapons, and ornaments. They developed methods to sharpen stone by using other stones or materials like deer antlers. Initially, early humans used natural resources like stone, bone, and wood to make tools. They had no knowledge of metal, but they did use vibrant minerals like hematite (iron ore) and malachite (copper ore) as pigments for body paint and decoration. These minerals are still used today in making paint.

The discovery of native copper marked a significant turning point.[11] Copper, one of the first metals used by humans, is found both naturally and in combination with other minerals.[12] Its colour varies from reddish-brown to shades of red, pink, blue, green, and black, depending on the minerals mixed with it. The use of copper dates back to the Chalcolithic period (around 4,000 to 6,000 BC), when it became widely used.[13]

The smelting of copper was developed independently in various parts of the world, including regions like Yugoslavia, where large underground mines were discovered dating back to before 4000 BC.[14] The Sumerians, one of the earliest civilizations, likely obtained their copper supplies from the surrounding mountains near Lake Van in Armenia.[15] The Egyptians, too, sourced their copper from local deposits, particularly malachite stones found in the hills near the Red Sea, which were connected to natural trade routes in the area.[16]

Traders in Cyprus began receiving copper pieces from Egypt around 2800 B.C., along with similar items that likely had Sumerian cuneiform writing on them. Around the same time, Cyprus began to develop its own copper mines, which gained recognition throughout the Eastern Mediterranean. Copper, like all elements, has its own chemical symbol—Cu, which comes from the Latin word *cuprum*, referring to Cyprus, the island that provided the ancient world with large amounts of copper.[17]

Copper and tin are sometimes found together in ores, and when these ores are melted, they form an alloy called bronze. At the time, bronze was more valuable than pure copper because it was much stronger and harder. The discovery of the copper-tin alloy marked the beginning of the Bronze Age.[18] Around 1500 B.C., the Bronze Age began in Europe,[19] and it reached its peak in China around 1529 B.C. during the Shang Dynasty. During this period, many beautifully decorated bronze items, both practical and ceremonial, were produced. Tin ores, which coexist with copper, were found in places like Wales, Spain, Turkey, and Siam (now Thailand). The Phoenicians likely brought bronze ingots to Egypt from Europe. These ingots, shaped like cakes, had a rounded, slightly thick profile that required carriers to rest them on their backs. Such scenes are depicted in Persian reliefs and Egyptian frescoes.[20]

Bronze was easier to cast than pure copper,[21] which made casting metal products much more practical. The Egyptians learned how to alloy copper with tin and sometimes a bit of lead to improve the metal's solidification properties. This innovation led to the production of a wide variety of items, including weapons, tools, bowls, figurines, vases, and sacred vessels.[22]

The use of bronze by the ancient Greeks was widespread.[23] Numerous types of items have been found in Greece, from large armor plates and statues to small, delicate figurines that served as handles or supports for mirrors and caskets.[24] Brass, a copper-zinc alloy, became widely used by the Romans after the Greek philosopher Aristotle introduced the metal to them around 330 B.C. The Romans called brass *Oreichalcos*, which means “brilliant white copper.” This was made by combining copper with tin and an earth material known as *Calmia* or calamine, a zinc carbonate found along the Black Sea coast. When copper and pulverized calamine ore were heated in a crucible, the zinc vapor penetrated the copper, creating brass.[25]

The terms "bronze" and "brass" did not exist in ancient times. The word “brass” emerged in Old English around 1200 AD, derived from the Middle English word *bras*.[26] During the Tudor period, brass was used to refer to any copper alloy, and this meaning carried over into the King James Bible. The Roman use of brass was primarily ornamental, and the alloys they used contained 11-28% zinc. Romans recognized that different grades of brass had different functions. They also used copper money widely, unlike the Greeks who used it much less.[27]

In the Middle Ages, brass was first used for military purposes. German forces used brass cannons during the 1331 siege of Cividdale in Italy, highlighting the value of brass as a material for weaponry. Edward III of England also used brass cannons in France, which led to the development of a metallurgical industry in England. The first recorded production of brass firearms in England occurred in 1385, when the Sheriff of Cumberland made three brass cannons.

Brass was not only used for weaponry during the Middle Ages; it also had artistic applications. Some of the most famous early examples include the Baptistery doors at Florence's Cathedral and brass bells. In addition, copper and brass were used to make decorative and functional items such as amphorae, jugs, plates, and enamelled goods. The famous brass works from the 15th and 16th centuries in Limoges, France, are considered masterpieces of this kind of art.

In the Orient, brass craftsmanship flourished during the medieval period. Exquisite brass Buddhas and other objects can still be found in temples in India, where artisans created massive statues and bells. The Ananda temple in Tirumalai, India, is particularly notable for its brass-covered exterior, which foreshadows modern design trends. In Japan, the earliest brass items, known as "dokatu," are copper bells found in many locations, suggesting that Japan may have been the birthplace of the oldest brass industry in the region. In the past, China was the main supplier of brass goods to Japan, including swords, kitchenware, and mirrors.[28]

Brass also played an important role in pre-Columbian America. Cultures such as the Toltecs, Aztecs, Moche, Nazca, and others in Central America and Peru had advanced metalworking techniques, including smelting, casting, and gilding.[29] They created both decorative and practical items from metal, including brass bells, fishing hooks, needles, and chisels. In North America, Native Americans used brass for tools, weapons, jewellery, and amulets, mainly made from native copper found around Lake Superior. Many copper artifacts have been discovered in burial mounds, dating from later centuries.[30]

Industrial Revolution:

The Industrial Revolution brought significant changes in the production of copper and its alloys, mainly driven by the increasing need for better raw materials. The introduction of steam-driven pumps allowed mines to be drained more efficiently, increasing productivity. The faster removal of impurities from ores contributed to higher processing efficiency. Technological advancements, particularly in electricity, also boosted demand for copper.[31]

In 1729, Stephan Grey made the first known attempt to transfer electric current using brass wire, and Sir William Watson expanded on this idea by using the Thames River as the return wire in 1747, successfully sending a current across Westminster Bridge. These experiments showed that metals, especially copper, were excellent conductors of electricity, surpassing even silver in some cases, even when copper was impure. This is likely why copper has been widely used for lightning conductors, as Benjamin Franklin used copper for this purpose.

In 1811, copper wire was used to protect ships from lightning strikes, and in 1799, Alessandro Volta created the first electric battery, using copper and zinc discs, which contributed to the development of the electric telegraph. This invention sparked the demand for copper wire, marking the beginning of the electrical communications industry. The invention of the stamping press also led to an increased demand for brass, as it made the production of items like metal buttons and furniture fittings more efficient and widespread.[32]

Brass, a combination of copper and zinc, has been a popular material in creating maritime instruments due to its resistance to corrosion, excellent machinability, ease of engraving, and non-magnetic properties. This made it ideal for marine compasses, which were mounted on brass gimbals and housed in brass bowls.[33]

In the field of electrical engineering, significant developments, such as Faraday's discovery of electromagnetic induction in 1831 and Edison's invention of the electric light bulb in 1878, led to greater demand for copper, particularly for the construction of electric power stations and telegraph cables. This trend accelerated in the late 19th century with the invention of the electric dynamo by Werner von Siemens in 1866, which boosted copper demand even further.[34]**Copper and brass saw a massive increase in global demand during the 19th and 20th centuries.**

Modern Era

By the end of the 19th century, global copper demand was around 500,000 metric tons, but by 1992, it had risen to 14.6 million metric tons.[35] This growth was driven by advances in construction, transportation, and electrical and electronic industries. The Asian market, in particular, was expected to see the largest increase in demand for copper.[36]

World Reserves:

The world's copper reserves are primarily located in South and North America, with significant deposits in countries like Chile, the United States, and Zambia. South America alone holds about 31% of global copper reserves, with Chile being the largest contributor.[37]

❖ Brief History of brass industries in India

India's history with brass dates back to the Indus Valley Civilization, around 2400–1700 BC,[38] with evidence of copper and brass working found in places like Kalibangan in Rajasthan, Lothal in Gujarat, and Mohenjodaro. Brass continued to be used in India throughout various periods, including the Maurya and Gupta periods, for making coins, tools, and sculptures.[39] The earliest use of copper and brass was in the creation of practical items like utensils and statues.[40]

Over time, the Indian craft of brassworking flourished, particularly in regions such as Pembarthi, which became famous for its brass crafts.[41-42] Brass and copper work remained a significant part of India's artistic and industrial traditions, and brass items continue to be produced in various parts of the country.[43]

India is the largest producer of brass in the world, a tradition that has been practiced for over five million years.[44] Brass work in India comes in many forms, and it is practiced in different regions. In the northern and northeastern parts of the country, places like Moradabad, Aligarh, Hathras, and Varanasi in Uttar Pradesh; Mayurbhang, Dhenkenal, Keonjhar, and Sundergarh in Orissa; and Jaipur and Jodhpur in Rajasthan are known for their brass industries.[45-47] In the southern and western parts, important brass clusters include Pembertha and Hyderabad in Andhra Pradesh, Bidar, Negamangala, Mysore, and Gadag in Karnataka, and Swamimalai, Madurai, and Tanjore in Tamil Nadu. Gujarat, Maharashtra, and other states also have significant brass industries, including Jamnagar, which is one of the biggest centres for brass components.[48-49]

Moradabad, Uttar Pradesh, is well known for its production of household items like trays, bowls, pots, and decorative pieces made from brass, copper, and white metal, often with delicate etching. Varanasi is famous for casting statues of gods and producing brass and copper household items.[50] Mirzapore in Uttar Pradesh is another important hub for brass utensil production, meeting both local and international demand. Lucknow is known for creating functional items with intricate designs, while other areas like Punjab and Bihar specialize in brass and copper utensils for local consumption.[51]

❖ Gujarat's Brass Industry History

Since the Chalcolithic copper-Stone Age, metal craftsmen have called Gujarat home. Locations of the Indus Civilization.[52]

The Harappan people, whose remains have been found in large quantities in Gujarat, are known to have been skilled in the forging, hammering, and casting of copper and bronze.[53] Aryans are likely to have been aware of the use of a metal known as ayas, which eventually came to mean iron but may have meant bronze or copper at that time.[54] One of the oldest and most notable boards of metal east objects of Gujarat is the one discovered at Akota, near Baroda. A metal bell from the sixth century and an incense burner from the ninth century from this board are perhaps the record metal objects of everyday art of Gujrat.[55]

Gujarati artisans have demonstrated exceptional skill in crafting cutlery as well. Any Gujarati home will have a range of shiny copper, brass, and iron containers, each with a shape and form appropriate for a certain purpose. Other examples of metal work found in Gujarat include votive figurines, nutcrackers, large dowry containers, incense burners, boxes for storing betel leaf and nut, and metal lamps.[56] Gujarat's metal artisans are called kansaras, a name derived from the Sanskrit word kansu, which means bronze. Prior to Before to the invention of brass, bronze cutlery was widely used.

Gifts and souvenirs of all kinds, including religious and other figures and nutcrackers, are perfect.[57] The well-known metal embellishments and engravings that are thought to be uniquely Gujarati are found in Kachchh and Rajkot. Cutlery, scissors, knives, and brass and iron kitchenware can be purchased in Anjar, Sinhor, Surendranagar, Dhrangadra, and Wadhawan. In addition, you can pick up blades and daggers with exquisite sheaths and hilts and observe the making of arrows.[58]
One of the biggest brass industries in India is located in Jamnagar. The majority of the nation's brass parts industry is located in the Jamnagar district, which supplies a wide range of industries including electronics, building hardware, automobiles, bicycles, and electrical appliances. It also meets the nation's need for about 70% of its machine brass components and exports some of its output to other nations.[59]

According to the report, Jamnagar's brass components business is over 60 years old. It all began in the late 1940s with the demise of the factories that made brass buttons. The absence of mechanised machinery was the primary factor in its demise. The high demand for their well-made buttons was more than they could provide. There were other factors as well, which contributed to the demand being drastically reduced when nylon buttons were developed in Japan. The firm found it impossible to survive in the cutthroat button industry.

The maker of brass buttons shifted their manufacturing to brass parts components with only slight modifications to the available machinery. The source of all inventions is necessity. This resulted in the growth of Jamnagar's brass machine industry. In Jamnagar, the casting also progressed concurrently with this. They managed to accomplish it in a very economical way.[60]

- **Unprocessed Materials**

Copper is the primary component of brass. The amount of copper present vary by weight, ranging from 55% to 95%, depending on the brass and its intended application. Brasses with a significant amount of are formed from electrically purified copper, which must be at least 99.3% pure in order to reduce the quantity of additional ingredients. Brass Objects can also be produced from less copper-containing materials. electrically pure copper, but are typically constructed from less-pricey scrap copper alloy recycled from. When repurposed waste is Used, the proportions of other minerals and copper in the scrap must be understood in order for the producer to modify the quantities of components that must be added to obtain the appropriate brass composition.

Zinc is the second part of brass. The zinc content varies.5% to 40% by weight, depending on the kind of brass. Brasses with higher zinc percentages are more robust and durable. however, they also have less corrosion and are harder to produce. opposition. Brass is manufactured from commercial-grade zinc. Known as spelter at times. Additionally, certain brasses have trace amounts of other elements to enhance specific qualities. Lead content of up to 3.8% by weight may be included to enhance machinability.

The addition of tin improves resistant against corrosion. Forging is the process of repeatedly impacting brass to form it into the desired shape. Iron hardens the brass and reduces the size of the internal grain structure. In order to prevent corrosion, brasses with more than 20% zinc occasionally have antimony and arsenic added. Additional materials that could be utilised in trace levels include silicon, phosphorus, and manganese.[61-62]

Further Alloying Additions:

Alloying additions are made to the basic copper-zinc alloys for a variety of reasons: -

→ To improve machinability

→ To improve strength

→ To improve corrosion resistance

→ For other special reasons

The enormous range of standard brass compositions that are offered is indicative of the various ways in which an ideal blend of characteristics can be customised to guarantee suitability for the intended use.

1. Lead percentage (Pb%):

High machinability, good strength, and exceptional casting properties are enhanced by the use of lead.

Lead is the most often added material to brasses to change their characteristics; alpha-beta brasses may have up to 4% of lead added to them to give them free-machining qualities. Lead is present in the alloy as a dispersed discontinuous phase that does not form a solid solution with the copper and zinc. The resistance to corrosion is unaffected. Because lead causes breaking during hot working when there is not enough beta phase, lead is not added to wrought alpha brasses.

Lead's lubricating capabilities provide excellent low friction and low wear characteristics for the plates, pinions, and gears found in instruments and clocks.

2. Tin [Sn%]:

In mining and marine settings, tin can be added to improve resistance to corrosion. It results in a little improvement in tensile strength and hardness.

The composition of naval brass (CZ112 and SCB4) and admiralty brass (CZ111) contains 1% tin. These brasses, as their names suggest, were first created for use in seawater applications; tin was added to improve corrosion resistance.

Brass that has less than 2% tin in it is less likely to corrode in seawater.

3. Iron (Fe%]:

An iron-based alloy is created when brass and iron are combined. Delta Metal is among them, with 55% copper, 41% zinc, and 1%–3% iron.

4**. The percentage of manganese**

As little as 0.02% manganese presence can produce stronger, more reliable castings, high welding qualities, and good corrosion resistance in maritime environments, making it a beneficial deoxidant. The most popular additions are iron and manganese, which together provide higher hardness, proof stress, and tensile strength with only somewhat less ductility.

5. Aluminium [Al%]:

When it comes to enhancing hardness, proof stress, and tensile strength, aluminium has the biggest impact. To get the best possible mix of attributes, tight control is required because of its impact on microstructure and ductility. Furthermore, the self-healing oxide film that aluminium provides improves corrosion resistance. In order to prevent the molten metal from contaminating the die materials, aluminium is added to create a protective oxide film. This film can easily accept a variety of surface finishes, has strong electrical and thermal conductivities, and is highly reflective of heat and light.

Compared to regular brass, aluminium brass (containing no more than 3% aluminium) is more resistant to corrosion.

6. Nickel (Ni%):

Without significantly affecting ductility, nickel increases hardness and tensile strength and confers better qualities at higher temperatures.

As exceptional brasses, the group of copper-nickel-zinc alloys known as "Nickel Silvers" and containing between 10 and 20% nickel can be considered. Rather than the usual brassy hue, they appear silvery. Although they exhibit corrosion characteristics that are mostly identical to those of alpha brasses, the higher nickel versions exhibit improved resistance to tarnish and stress corrosion cracking.

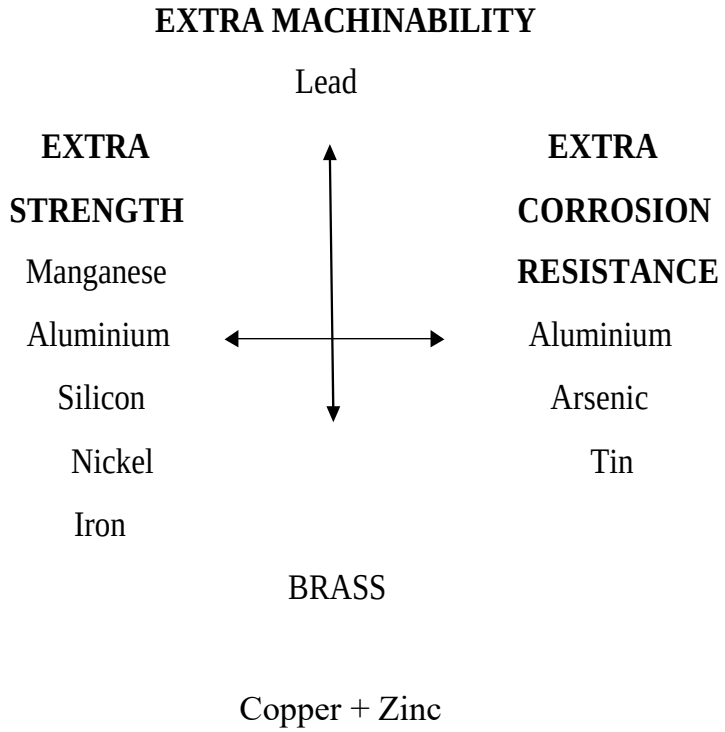
7**. Silicon**

In addition to giving brass more strength, silicon is occasionally used to filler alloys for gas welding and die casting brasses to help with fluidity and lessen zinc oxidation. From the perspective of corrosion, its main result is an increase in the beta phase content.

8. Arsenic

Alpha brass alloys are frequently treated with minor quantities of arsenic to prevent dezincification corrosion.

The previously described point can be summarised as follows:



[Source: According to reference no.[63]]

❖ Create

The conventional names for different kinds of brass typically represented either the material's colour or its intended application. For instance, red Brass was reddish in colour and included 15% zinc, whereas yellow Brass was yellowish in colour and contained 35% zinc. Brass cartridges comprised 30% zinc and was utilised in the production of gun cartridges.

Naval brasses were utilised in a variety of applications and contained up to 39.7% zinc.applications on board a ship. Regretfully, along with the conventional brass names were a quantity of misnomers. 10% zinc in brass was referred to as commercial. bronze, even though it wasn't actually a bronze and didn't contain any tin.

Architectural bronze is a brass that has 3.8% lead and 40% zinc.despite the fact that it was a leaded brass instead. Because of these occasionally ambiguous nomenclature, brasses in the United States are currently identified using the Uniform Numbering System. Metals and alloys system. This system employs a letter, which is the copper letter "C" (brass is an alloy of copper), which was followed by five numbers. Brasses with a chemical makeup that makes them appropriate for being mechanically shaped into the finished product techniques like forging or rolling are referred to as wrought brasses, and I through 7 is the initial digit of their designation. Brass objects whose

❖ Brass Types

In general, brass is an alloy of copper and zinc that is yellowish in colour. It also contains trace amounts of other metals, although the ratio is usually 67 percent copper to 33 percent zinc. Brass has been utilised extensively in the production of utensils, ornaments, and other items. After considering the above points, it can be said that the term "brass" solely refers to copper and zinc alloys.[64]

The amounts and quality of zinc and copper are the only factors that determine an object's strength and adaptability made of brass. Brass is created when copper and zinc are combined effectively.[65] Brass is frequently referred to as a replacement alloy globally.

We can group the many varieties of brass according to their applications, uses, and other factors, as listed below. The main varieties of brass are as follows:

1 Yellow Brass: The American phrase for 65% Cu - 35% Zn is yellow brass. It has outstanding cold workability. Brass can be used to make plumbing brass items locks, hinges, plumbing accessories, flashlight shells, lamp fixtures, radiator cores and tanks, fasteners, screws, springs, grill work, stencils and pins and rivets.

2. **White Brass:** White brass is too fragile for everyday usage and has a zinc content of above 50%.

3. **Red Brass:** The American word for gunmetal, a CuZnSn alloy, is "red brass." It has good hot formability and exceptional cold workability. Weather-stripping, conduit, sockets, fasteners, fire extinguishers, plumbing pipe, radiator cores, condenser and heat exchanger tubing, and other items can all be utilised with it.

4. Forging Brass: There are 59.5% Cu, 2.0% Pb, and 38.0% Zn in forging brass. It has outstanding hot workability. Hot heading and upsetting, machining, and fabricated heading and upsetting. It is suitable for all types of forgings and pressings.

5. **Cartridge Brass:** Cartridge brass has good cold working qualities and is composed of 70% copper and 30% zinc. Radiator cores and tanks, torch shells, lamp fittings, fasteners, screws, springs, grill work, stencils, locks made of brass for plumbing, hinges, plumbing accessories, pins and rivets are some examples of applications.

6.**High Brass:** High brass has a high tensile strength, is composed of 65% copper and 35% zinc, and is both well machinable and moderately workable when cold. Clock components, lock tumblers, strike plates, templates, type characters, washers, wear plates, gears, wheels, and channel plates are just a few of the applications for it. Other uses include book dies, hinges, hose couplings, clock plates and nuts, and clock and watch backs.

7. **Low Brass:** Low brass is a copper-zinc alloy with a light golden colour, good ductility, cold workability, and a composition of 80% copper and 20% zinc. manufacturing features and is utilised in the production of flexible metal hoses, metal bellows, battery cap bellows, clock dials, musical instruments, pump lines, and flexible hoses.

8. **Free Cutting Brass:** Brass used for free cutting has 61.5% Cu, 3.1% Pb, and 35.4% Zn. Excellent machinability can be achieved by rolling, threading, and knurling it. It is utilised for gears, pinions, and parts for automatic high-speed screw machines.

9. **Naval Brass:** The composition of naval brass is 60.0% Cu, 39.2% Zn, and 0.8% Sn. It is made via blanking, drawing, bending and upsetting, hot forging, and pressing, and has outstanding hot workability and hot forgeability. It is used in rivets, valve stems, condenser plates, aviation turnbuckle barrels, balls, bolts, marine hardware, nuts, and propeller shafts.

10. Admiralty Brass: Admiralty brass resists dezincification in the majority of settings because it includes 30% zinc and 1% tin.

11. **Silicone Red Brass:** Silicone red brass is composed of 4.0% Si, 14.5% Zn, and 81.5% Cu. It has outstanding hot formability or fabrication through screw machine operations and forging. It is used in valve stems where high strength and resistance to corrosion are essential.

12.**Alpha Brass:** Alpha brasses are employed in pressing, forging, and related processes. They have less than 35% zinc content, are pliable, and may be worked cold. They only have a single phase that is face-centered. crystal structure in cubic form. Rupert's metal, sometimes known as Prince's metal, is an alpha brass that is composed of 25% zinc and 75% copper. It is utilised as a gold mimic because of its exquisite yellow colour.

13. **Alpha-beta Brass:** Muntz metal, commonly referred to as duplex brass, has 35–45% zinc and is appropriate for hot working. It has both α and β' phases; β' is a body-centered cubic phase that is stronger and harder than α. Typically, alpha-beta brasses are worked hot.

14. **Beta Brass:** With a 45–50% zinc content, beta brasses are less ductile than alpha kinds and typically need to be cast or heated wrought before being formed into useable items. What is It's interesting to note that, compared to alpha brasses, beta brasses have comparatively better corrosion resistance despite having less copper. Thus, heat exchange tubing, architectural panel sheets, and maritime hardware are among the commercial uses for beta brasses.

15. **Aluminium Brass:** The composition of aluminium brass is 77.5% Cu, 20.5% Zn, and 2.0% Al, which enhances its resistance to corrosion and outstanding cold workability for bending and shaping. Ferrules, distiller tubing, condenser tubing plates, evaporator and heat exchanger tubing, and condenser tubing are examples of applications.

16. **Arsenical Brass:** Boiler fireboxes use arsenical brass, which has an addition of arsenic and often aluminium.

17. Manganese Brass: In the United States, manganese brass is most famously used to designate golden dollar coins. It is composed of approximately 70% copper, 29% zinc, and 1.3% manganese. It may be shaped, bent, stamped, welded, and bended with great cold formability.

18. Common Brass: Common brass, often known as rivet brass, is an inexpensive, common cold working brass with 37% zinc.

19. Rich Low Brass: 15% of rich low brass is zinc. It is frequently applied to jewellery.

20. **Tonval Brass:** An alloy of copper, lead, and zinc is tonval brass. Its susceptibility to dezincification makes it unsuitable for usage in seawater.

21. **Free Machining brasses:** Generally speaking, free-machining brass has a 58% copper content and a 39% zinc content. The use of lead enhances machinability. To increase strength and resistance to corrosion, additional elements including silicon, manganese, tin, aluminium, iron, and arsenic can be added. Typically, free-machining brass contain about 58% & 39% copper & zinc respectively. Lead is added to improve machinability. Addition of other parts such as manganese, tin, aluminium, iron, silicon & arsenic may be used to improve strength resistance.[66]

❖ The Method of Manufacturing:

The production process that goes into making brass entails mixing the right basic ingredients to create a molten metal, which is given time to harden. The characteristics and form of the solidified after which the metal undergo a sequence of meticulously regulated procedures to generate the required brass inventory.

There are numerous varieties of brass stock to choose from, such as plate, sheet, strip, foil, wire, bar, billet, and rod based on the ultimate usage. For instance, lengths of rod are trimmed to size to make brass screws. Certain car radiators feature zigzag fins that are bent from strip. Rectangular pieces are squeezed or extruded to create pipes and tubes. billets of heated brass through a die—a shaped opening—to create elongated, hollow tubes.

The general distinctions among plate, sheet, strip, and foil thickness and dimensions of the materials. Plate is a big, rectangular, flat object. a section of brass thicker than roughly 0.2 inches. (5 mm)—similar to a piece of plywood used for building. Sheet typically is thinner than the plate but has the same overall size. Strip is constructed from sheet that has been divided into long, thin segments. Similar to a strip, foil only significantly thinner. There are some brass foils that are as thin as 0.0005 in.(Millimetres: 0.013).

The intended shape and the manufacturing process itself determine the actual characteristics of the brass stock and the specific equipment and procedures applied in various brass plants. This is an example of Method of manufacture for brass strips and sheets.

Melting

• A reasonable amount of scrap copper alloy is weighed. And placed inside an electric furnace, where it melts at around 1,920°F (or 1,050°C). After accounting for the zinc content of t scrap alloy, once the copper is added, the proper amount of zinc is added. Melts. A tiny quantity of extra zinc—roughly 50% of the total—zinc needed, can be supplemented to make up for any zinc that evaporates while the melting process is underway. Should any additional items be If necessary for the specific brass formulation, they are additionally added. The copper scrap did not contain them.

• Moulds measuring approximately 8 inches by 18 inches by 10 feet (20cm x 46 cm x 3 m) and left to set into what are known as cakes, which are slabs. Melting and pouring are sometimes done in semi-automated processes. Consistently to create extremely lengthy slabs.

• The cakes are emptied out after they are cold enough to handle. Of the moulds and transferred to the rolling area for storage. Warm rolling A furnace is used to warm the cakes till they reach the ideal temperature. The temperature is determined by the ultimate characteristics and form of the brass stock.

- Following that, the hot cakes are fed through a succession of opposing steel rollers that gradually lower the brass's thickness to around 13 mm, or less, or 0.5 in. Additionally, the breadth of the brass rises. This technique is also known as breakdown rolling.

- After cooling significantly, the brass goes through a milling apparatus known as a scalper. This device removes a thin layer of the brasses outside surfaces to eliminate any potential oxides developed on the surfaces as a result of the heated metal coming into contact with the air.

• Working with hot-rolled brass becomes more challenging as it becomes tougher. It likewise loses its ductility, or capacity for additional stretching. Prior to the Before brass can be further rolled, heat must be applied to remove some of its ductility and increase its hardness. This procedure is known as annealing. The differences in annealing temperatures and periods are based on the desired qualities and composition of brass. Bigger portions of hot One way to anneal rolled brass is to put it in a sealed furnace. Collectively in a batch. Smaller parts could be fastened to a metal belt. Conveyor and fed continuously via an airtightly sealed furnace at every point. Using either approach, the furnace's interior atmosphere is containing a neutral gas, such as nitrogen, to stop the brass from interacting with oxygen to produce unwanted oxides on the surface.

• Following annealing, the brass pieces are run through a further set of rollers to further thin them out to around 0.1 inch (2.5 mm). The reason this technique is known as "cold rolling" is because the The temperature of brass is substantially lower than that of hot rolling. Chilly Rolling causes the brass's internal structure, or grain, to distort. Enhances its hardness and strength. The greater the thickness, decreased, the material gets tougher and stronger. The chilly The purpose of rolling mill design is to reduce deflection over the breadth Using the rollers to create brass sheets that are almost consistent in thickness.

• To get the intended result, steps 7 and 8 may be performed numerous times. Strength, thickness, and level of hardness. In certain plants, the Brass components are joined to form a single, continuous object. Sheet and are put through a sequence of rolling mills and annealing furnaces. Mills set up in a serpentine pattern vertically.

• The large sheets might now be cut into smaller pieces to make a strip of brass. After that, the strip can receive an acid bath and to clean it, rinse. Complete the roll.

• To tighten the sheets, one last cold roll may be applied. Tolerances for thickness or to create an extremely smooth surface conclude. After that, they are sized, stacked, or coils based on its intended application and thickness, and then sent to the warehouse for distribution.

• Before being sliced, the strip could additionally receive one last roll to sent to the warehouse after being coiled to length.

Control of Quality

Brass is continuously assessed during the manufacturing process and control over the ingredients and methods required to make a particular type of brass stock. The raw materials' chemical compositions are examined. And made adjustments prior to melting. The durations of the heating and cooling Temperatures are recorded and kept track of. The degree to which Every step involves measuring the sheet and the strip. Lastly, illustrations of the final product is examined for size, strength, hardness, and additional elements to make sure they fulfil the necessary requirements. Given that brass may be transformed into a variety of Due to its various patterns, shapes, and acoustic qualities, brass has emerged as a highly favoured material for a wide range of uses.

Brass has numerous qualities, including the following:

1.Outstanding Machinability:

Brass may be machined at a lower cost than mild steel.

• All brasses have an inherent ease of machining

• This feature is further enhanced by the addition of trace amounts of lead to brasses, which also somewhat reduces their ductility.

• "Free machining brass" establishes the benchmark for machinability assessments of other materials.

• Lower rates of tool wear and faster machining speeds reduce total production costs.

• Excellent surface quality and tolerance holding are maintained throughout lengthy manufacturing cycles.

2.Strong Points:

• Brasses are ductile and robust when softened or annealed, but their strength increases significantly when they are hardened using cold working methods like rolling or drawing. Sections that are drawn and extruded can be combined to create robust, rigid structures. Containers and other pressurised plant equipment can be constructed from bars, rolled sheet, and plate.

• Brasses compare favourably to many alternative materials because their strength is mostly retained up to 200°C and only slightly reduced at 300°C.
• Because the qualities of the brasses are either maintained or slightly enhanced at cryogenic temperatures, they are highly ideal for usage in these settings.
• "High tensile brasses" are offered for applications requiring higher strengths. These have extra alloying components, which enhance the qualities even more.[70]

3.Dependability:

• When pressing, deep drawing, spinning, and other cold forming techniques are utilised to create complicated components, brass with a copper concentration of more than 63% can be substantially deformed at room temperature.
• The ductility at room temperature is decreased if the copper concentration is less than 63% and no additional alloying elements are present. However, these alloys can still be extensively hot worked by rolling, extrusion, forging, and stamping.
• The alloys' ability to maintain strength, ductility, and formability at low temperatures makes them perfect for cryogenic applications.

4.Conductivity:

• When it comes to electrical and thermal conductivities, brasses outperform ferrous alloys, alloys based on nickel, and titanium.
• Due to their corrosion resistance and comparatively high conductivity, they are the perfect material to be used in the production of industrial and household electrical equipment.
• Copper and its alloys must have strong thermal conductivity for the tubing used in condensers and heat exchangers.

5.Simple Enrollment:

Brasses can be easily attached to other metals or copper alloys using the majority of commercial joining techniques, including:

• Riveting
• Soldering with soft solder
• Forging
• Welding friction
• Contemporary adhesive joining techniques

6.Not igniting:

Brasses are certified for usage in hazardous situations and do not ignite when struck.

7.Good Resistance to Corrosion:

Because of their superior corrosion resistance, brasses are a natural and cost-effective first option for a wide range of applications.

• When brasses are exposed to the atmosphere, a thin, visually appealing green "patina" forms around them as protection.
• Unlike iron and steel, which corrode away with time, brass will effectively remain unaltered for an infinite amount of time.
• Brass tubes and tube fittings, valves, etc. have a long history of usage in home plumbing, central heating, and other applications. Seawater can be handled successfully as long as the right alloy is selected. Desalination plant, steam condensers, and seawater lines.
• Manganese-containing high-tensile brasses are very resistant to air corrosion; prolonged exposure causes the bronze colour to gradually darken.[71]

8.Wear Resistant:

Lead's lubricating capabilities provide excellent low friction and low wear characteristics for the plates, pinions, and gears found in instruments and clocks.

There are specific brasses that have silicon added to them, which makes the material perfect for heavy-duty bearings.[72]

9.Plating:

• Brasses can be high-surface-finished and simply repolished when needed. They can also be lacquered to maintain their original colour or enamelled or plated with chromium, nickel, tin, silver, gold, etc. as needed. As an alternative, the surface can be toned to a variety of colours, starting with "bronze" Using a range of brown tones, blue-black, and black toning compounds that are sold commercially. Architectural and ornamental metals are common uses for these colourful finishes.

• Any kind of standard plating procedure can be applied. It is customary to utilise a copper plate underlayer for many other metals. Brass is quickly polished and does not require the initial cost of a copper strike; therefore this is not necessary. Cadmium plating brass was a classic method of providing additional corrosion protection to steel when used against brass; however, zinc plating has mostly supplanted this practice.[73]

10.Appealing Colour:

Brass is widely utilised for long-lasting decorative applications and the production of utilitarian objects where long-term service life and aesthetic appeal are required.

• The addition of different percentages of zinc to brasses tones the red of copper to a variety of pleasing yellow hues, ranging from the gold-like colours of the 95/5, 90/10, 85/15, and 80/20 alloys—properly referred to as "gilding metals"—through the greater slight changes to the richer yellow colour of the 60/40 alloy, historically known as "yellow metal," in the 70/30, 2/1, and 64/36 family of brasses.

• The shine of aluminium brasses is distinctly silvery.

• When extruded, some brasses that have manganese added to them have an appealing bronze tint.

• Because they can be patinated to a variety of resilient brown and bronze finishes, high tensile brasses—some of which are also referred to as "manganese brasses" or, in the past, "manganese bronzes"—are especially well-suited for architectural applications.[74]

11.Cleanliness:

Since copper is a well-known biocide, brasses' copper component has the advantageous effect of preventing the growth of microorganisms. Experiments conducted on door hardware, including knobs and kick plates, have demonstrated that brass is significantly less likely than other materials to promote the growth of microorganisms that cause nosocomial infections. Brass fixtures, devoid of further

Therefore, critical areas like hospitals should utilise protective finishes.[75]

12.Permeability to magnetism:

Because of its fundamental non-magnetic nature, brasses are widely used in instrumentation such as geological and survey equipment, as well as electrical and electronic equipment.[76]

13.Castability:

Strong, sound castings can be easily produced from any brass, catering to a broad range of end customers. A number of the most widely used alloys are covered by both the new BS EN specification and the outdated BS1400 specification. Some of these alloys have tin added for strength and corrosion resistance, and lead added for better machinability. Manganese is a helpful deoxidant; castings with as little as 0.02% manganese present are stronger and sounder. The 60/40 type alloys are employed in die-casting.[77] The higher zinc content reduces the casting temperature and provides necessary hot ductility. In order to prevent contamination of the molten metal and lessen the impact on the die materials, aluminium is added to create a protective oxide film. This kind of alloy featuring an appropriately regulated. For castings that must be resistant to dezincification, composition may also be utilized.[78] Complex shapes are best produced using the casting method. Pipeline valves and electrical switchgear components, which demand high strength and soundness, are examples of end users. a long service life, as well as spark-resistant qualities in the case of components for the mining and petrochemical industries, to non-critical ornamental applications where both a long service life and a good surface finish are required.[79]

14.Forms and Properties Available:

Brasses may be made into a vast array of shapes because they are easily fashioned through hot and cold working methods. Semi-fabricated stock comes in a variety of forms, including drawn and extruded bars, curved sections, hollow rods, tubes, and wire, as well as rolled plate, sheet, strip, and foil. Hot stampings, forgings, sand castings, shell moulded castings, gravity and pressure diecasting's, and investment castings are among the forms of intermediate products that can be acquired. The accessibility of these Quantity requirements may apply to things that must meet precise composition and size standards. The relevant British Standards for the wrought goods give dimensional tolerances adequate for most general engineering applications.[80] Special requirements should be negotiated with manufacturers.

15. Cost-effectiveness:

The low cost of brass components is a result of numerous, occasionally disregarded variables.

- To save finishing expenses, close tolerance manufacturing techniques might be used.
- Tooling expenses could be far cheaper than those associated with other materials or procedures.
- The ability to reduce manufacturing costs is facilitated by the ease of machining.
- Compared to many other materials, brasses have a reduced cost of protective finishing due to their superior corrosion resistance.[81]

In India, the states of Gujarat, Haryana, Orissa, Assam, and Uttar Pradesh are home to the brass metal sector. However, there is a little distinction between the goods produced in these three states. While most products created in Gujarat are brass machined components, most products manufactured in Haryana, Orissa, Assam, and Uttar Pradesh are brass metal handicrafts and utility items constructed out of sheet metal components or single piece casting. The goods produced in Uttar Pradesh, Orissa, Assam, and Haryana are consumer goods that are utilised as gifts, functional objects, or decorative pieces, depending on how they are applied or used. On the other hand, goods produced in Gujarat can be categorised as industrial goods that are used by businesses as a portion of or component of their finished goods. Gujarat produces brass parts that require a lot of machining operations, such as turning, milling, grinding, drawing, boring, threading, and so on, in contrast to the other four states.

OVERVIEW OF THE BRASS PART INDUSTRY IN JAMNAGAR DISTRICT

The brass parts industry in Jamnagar plays a crucial role as a key supplier of brass components to various engineering sectors, including automotive, electrical, and electronics. The industry's remarkable growth can be attributed to the expansion of these sectors. Jamnagar is famously known as "Brass City," "Paris of Saurashtra," and "Chhoti Kashi" and has a rich history dating back to the era of Jam Hala, who conquered parts of Saurashtra and established the region.[82] Jamnagar, located in the northwest of Gujarat, covers an area of 14,125 sq. km. and is bordered by the Gulf of Kutch, Rajkot, Junagadh, and the Arabian Sea.[83]

The brass industry in Jamnagar began in the 1940s with small brass button makers and has evolved into a thriving sector, generating about Rs. 700 crores in revenue[84]. There are now approximately 4,500 units producing over 10,000 brass items, in addition to 3,500 home-based businesses that contribute to employment and production. Jamnagar's brass industry provides jobs for around 150,000 people, making it a significant economic hub.[85]

❖ History & Evaluation of Brass Parts Industry in Jamnagar District:

Historically, Jamnagar's brass parts industry has been a major contributor to Gujarat's manufacturing sector, supplying about 70% of India's machine brass components, with significant exports. The industry has served various sectors, including building hardware, automotive, bicycles, electronics, and electrical appliances.[86] According to reports, Jamnagar's brass parts industry began over 60 years ago when the brass button units began facing difficulties in the late 1940s due to the lack of mechanized machinery and the rise of nylon buttons.[87] As a result, the brass button manufacturers pivoted to producing brass parts using their existing machinery, which led to the growth of the brass machine industry in Jamnagar.

A significant contributor to this development was Mr. Madhavdas Ravji Ashar, who, in the 1940s, established the first hardware factory, "SVI," producing brass items such as locks and handles. He was later joined by other innovators who developed machinery to meet the technological needs of the industry. By the early 1950s, several brass hardware factories had emerged in Jamnagar, mostly founded by former workers from Mr. Ashar's factory. Among them was a group of six young

entrepreneurs who started producing brass screws in 1952, and by the mid-1970s, only a few factories, including those of Mr. Ratan Singh Bhanji and Mr. Vishnubhai Sujanmal Khatar, remained in operation.

The increasing demand for brass components led to the establishment of casting units in the 1950s, with key figures like Mr. Ghelabhai Kanha Bhai and Mr. Bhagwanjibhai Mistry setting up casting facilities to meet the needs of the growing brass industry. These developments marked the beginning of "job work units" in Jamnagar.[88] In response to technological challenges, several mechanics in the region began creating machines for drilling, turning, threading, and other processes. These innovations led to the creation of affordable, high-quality turning machines known as THADAS, which became widely used by brass component manufacturers.[89]

A major milestone came in 1968 when Mr. Mohan Bhai, the owner of Janta Engineering, developed the first automated system for producing both nylon buttons and brass components. Over time, the local development of technology in Jamnagar led to machines that were ideally suited for the brass industry. The establishment of the Gujarat Industrial Development Corporation (GIDC) in 1969, followed by the development of industrial estates in 1983, played a significant role in further boosting the brass components sector in Jamnagar. These public and private industrial developments contributed to the continued growth and modernization of Jamnagar's brass industry.

In the early 1960s, the brass components industry in Jamnagar began to grow significantly due to the rising demand for small parts used in electrical fittings and appliances. This expansion was a key turning point for the industry, with the period between 1960 and 1970 being particularly prosperous. During this time, the industry saw tremendous growth and diversification, and it laid the foundation for Jamnagar to develop the technological capabilities required to produce high-precision parts for sectors like computers, telecommunications, electronics, and space exploration.[90]

As bicycle manufacturing in India rapidly expanded between 1960 and 1970, the demand for brass components, such as bicycle tube valves, spoke nipples, and other parts, grew significantly. Prior to this, most of these components were imported from Japan. In response to this demand, Jamnagar started producing bicycle tube valves in the early 1970s.

Today, around 35 to 40 companies in Jamnagar produce bicycle-related brass components, controlling over 97% of the national market share for these products. Additionally, Jamnagar began producing automobile parts and sanitary fittings, which had previously been imported from Japan.

The quality of the products needed to be improved, especially since the sand-casting technology initially used to make brass components produced low-quality results. Jodhpur, Rajasthan, which had an extrusion facility using virgin metal, became a source of high-quality brass parts. To address this gap in production, the first extrusion plant in Jamnagar, named Rajalaxmi Metals, was established in 1981. This facility was the first to use scrap brass for extrusion, and by 1989, another similar facility, Rajhans, was set up. Today, there are six extrusion plants in Jamnagar that meet the industry's demand for high-quality inputs.

In 1977, the Government of India adopted a liberal policy that allowed entrepreneurs to import brass scrap, which further encouraged the growth of the industry. The policy changes in the late 1980s, which allowed the import of brass, gave the industry an even greater boost. By this time, small and medium-sized enterprises (SMEs) in Jamnagar began focusing on high-precision brass parts for electronics, telecommunications, and computers. This new phase of precision manufacturing began in the late 1980s and continued to grow in the 1990s.[91]

Over the decades, Jamnagar's brass industry has transformed from producing basic brass buttons in the 1940s to manufacturing high-end precision parts by the 1990s.[92] The industry now produces a diverse range of products, including building hardware, screws, electrical components, bicycle parts, automobile parts, sanitary fittings, safety razors, battery terminals, cable glands, and even pencil sharpeners. Despite the fact that Jamnagar does not have a large local market or a direct supply of raw materials (since 94% of brass scrap is imported), the concentration of this industry in Jamnagar is due to the enterprising spirit of its people and the extensive knowledge they have accumulated over the years. This has allowed the industry to establish itself and thrive since its inception in the 1940s.

Historical Growth of Brass Parts Industries in Jamnagar District

Sr. No.	*Year*	*No. of units*
1.	1952	1
2.	1954-55	15
3.	1960-61	250
4.	1967-68	700
5.	1979-80	1200
6.	1988	3000
7.	1994	3500
8.	1998	4500
9.	2002	4000
10.	2005	4500
11.	2010	5000
12.	At Present	More than 6000

(Sources: Indian Engineering Exports, Page No.40)

(Table 1.2.1 Growth of Brass Parts Industries)

Over the past 50 years, Jamnagar has become a major center for producing brass components, with around 4,500 factories in operation. The industry directly employs about 50,000 people and indirectly supports the livelihoods of nearly a million individuals. Alongside the factories, there are around 400 brass foundries, 130 electroplating facilities, and other metal finishing plants. These foundries provide the raw materials required for local manufacturing. The majority of these foundries use coke for fuel, while about 20-25 use oil. On average, around 280-300 metric tonnes of brass scrap are recycled every day.[93]

The total value of the goods produced in Jamnagar's brass industry amounts to Rs 960 crore annually. Out of this, brass components worth Rs 392 crore are exported, while the remaining products are sold within the domestic market. Despite importing 95% of its scrap brass, only about 20-22% of the total turnover comes from exports. The most common exports include bicycle tube valves, auto valves, battery terminals, safety razors, precision computer and telecom parts, and parts used in aircraft and spacecraft. Over the past five to seven years, the export growth rate has been about 15% annually.[94]

The types of products made in Jamnagar include precision components (5%), building hardware (25%), automotive and cycle tube valves (35%), sanitary and bathroom fittings (15%), and various other items (20%). There are almost 10,000 different types of brass parts produced in the city, most of which are small-sized components, although the range of products increases when considering different sizes and specifications. New parts are being introduced regularly, but many manufacturers only produce parts based on customer designs, making them unaware of the final use of their products.[95]

Jamnagar's brass parts are well-recognized globally, with the city being one of the largest producers of cycle tube valves and auto parts worldwide. These components are exported to markets in North America, Europe, and several other countries, including the UK, US, Canada, the Middle East, and Southeast Asia. The products are highly regarded for their accuracy and quality.[96]

The growth of the brass parts industry in Jamnagar occurred naturally due to a combination of factors. Initially, a few entrepreneurs started producing basic brass parts like bulb holders, screws, and pins, which attracted more businesses to the area. Several key factors supported this growth. Firstly, raw materials like brass scrap and other by-products became affordable and easily accessible in Jamnagar, which made it easier for manufacturers to obtain what they needed. Secondly, the city had a skilled workforce, with many workers from agriculture, small-scale farming, and salt industries transitioning to brass manufacturing, as it offered better pay. Thirdly, Jamnagar's ability to produce customized machinery for manufacturing provided flexibility in production, enabling businesses to meet various demands.

Another key factor was the presence of well-developed ports in Jamnagar, such as Rosi Bandar and Bedi Bandar, which facilitated the export and import of goods. These ports played an important role in the growth of various industries, including the brass parts industry. Additionally, Jamnagar's soil, known as "chikni mitti," was believed to contribute to the high-quality brass castings produced there, further supporting the industry's expansion.[97]

The Gujarat government has also played a role in promoting the industry, offering loans on favourable terms and providing infrastructure like industrial estates. The availability of land, water, and electricity helped attract more businesses to the area. Furthermore, the entrepreneurial spirit of the people in Gujarat, particularly from the Saurashtra region, has been vital to the industry's growth. The willingness to take risks and seize business opportunities, along with the demonstration effect of successful entrepreneurs, contributed to the industry's development.

The local market also supported the industry, as businesses in cities like Calcutta, Mumbai, and Delhi began sourcing brass parts from Jamnagar. As the demand for high-quality brass components grew, Jamnagar manufacturers shifted from producing low-quality goods to focusing on precision components, which were in demand in developed countries like Germany, Italy, the US, and Japan. By the late 1970s and early 1980s, they began exporting these products to these countries, further expanding their reach.[98]

All these factors combined to help the brass parts industry in Jamnagar grow into a thriving sector, producing a wide range of products for various industries, both locally and globally.
The structure of the brass parts industry in Jamnagar is unique, with small-scale industries making up over 98% of the total production. Larger companies tend to focus on specific products like extrusion machines, bicycles, tube valves, and electrical goods, and require more significant investments.[99]

The brass components industry in Jamnagar can be divided into several categories, based on a field survey and discussions with Mr. Gangadashbhai, the chairperson of the Factory Owners Association:

Category 1: Importers and Distributors

This category includes businesspeople who import honey and brass scrap to distribute to local manufacturers. These importers can benefit from a 10% rebate on import duties for orders over 500 tonnes annually, as per government policy. This has encouraged the establishment of large, financially stable importers who buy scrap and deliver it to the manufacturers based on their specifications. These importers often get discounts for large orders. Around 20 major importers operate in Jamnagar, making this a specialized industry in the region.

Category 2: Casting Units

Casting units play a crucial role in the production process. In these foundries, locally available pale and dross are melted together with imported scrap and honey to create different shapes and sizes. The basic raw material, which is the casting, is then sent to the machining units for further processing. There are around 400 brass foundries in Jamnagar, with 20–25 of them using oil as fuel, and the rest using coke. Quality control is essential at this stage, as any flaws in the casting can lead to poor-quality parts. Producing high-quality castings with minimal flaws requires significant technical expertise, making this one of the more challenging sectors in Jamnagar's brass industry.

Category 3: Machinery Units

Machinery units are vital in shaping the cast components into their final form. In Jamnagar, there is a wide range of machines available, including machines for drawing, milling, turning, drilling, cutting, and threading, as well as grinding and other specialized machines. These machines are used alongside tools, jigs, fixtures, motors, and quality control instruments to manufacture the final brass products. The majority of value creation in the manufacturing process happens during the machining phase, which involves complex techniques that require extensive technical training and technological advancement. Approximately 5,000 businesses in Jamnagar are involved in the brass parts machining industry.

Category 4: Electroplating Units

The electroplating units are the final stage in the brass components production process. Electroplating is used on certain brass parts, such as electrical accessories and electronics, but not all brass products require plating. This phase is important as it allows clients to detect any flaws in the product. Jamnagar has around 130 electroplating units that primarily handle large manufacturers' tasks and help finish the products before they are sold.

Category 5: Exporters, Marketing Agents, and Traders

This category includes exporters, marketing agents, merchant traders, and dealers. These individuals play a key role in selling around 80% of the brass parts produced in Jamnagar. Manufacturers typically sell their products to these traders, who in turn export the goods or sell them domestically. Marketing is a vital part of this category, as it adds value to the products, although it doesn't significantly enhance the quality. Large traders are primarily based in cities like Calcutta, Mumbai, and New Delhi, where they facilitate both domestic and international sales. Around 250 traders/exporters, both large and small, are involved in this part of the industry.

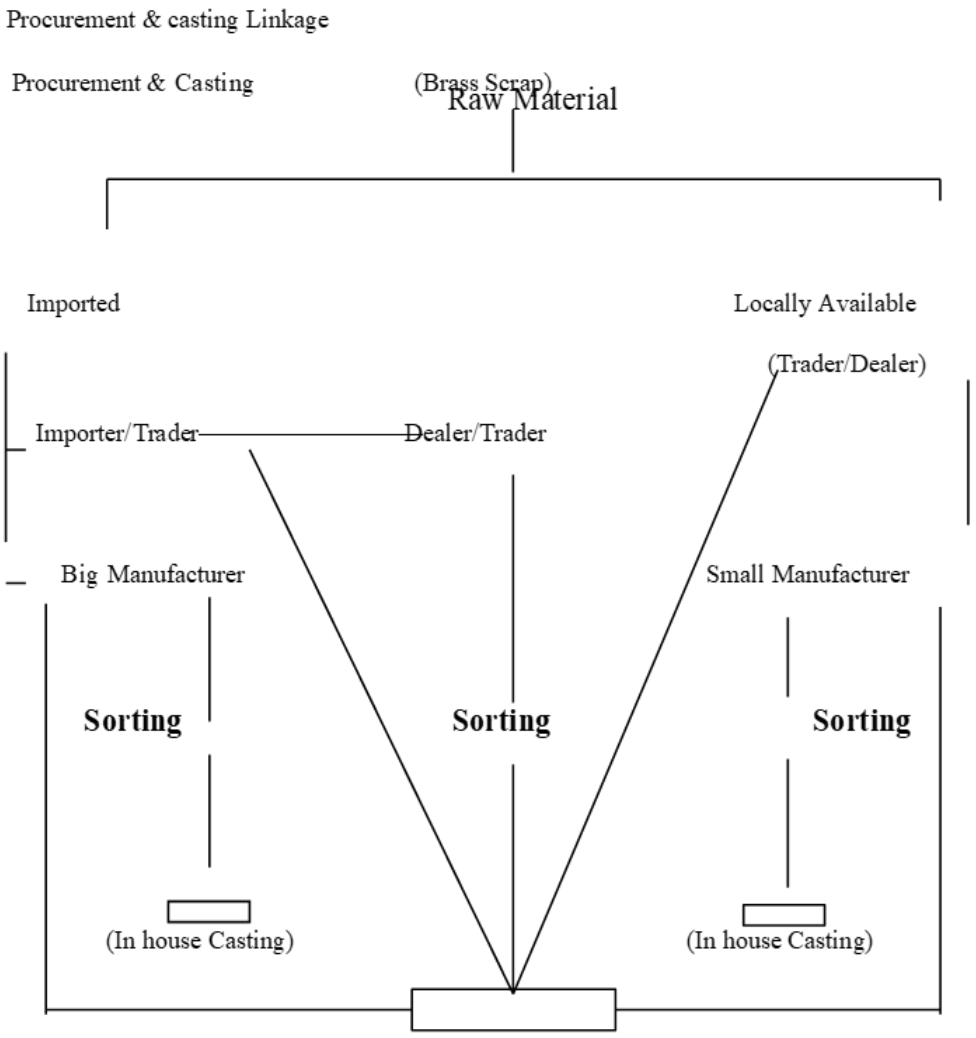
Category 6: Suppliers of Materials and Equipment

This category includes businesses that supply machinery, tools, and other essential materials like crucibles, furnaces, jigs, fixtures, molasses, coke, and measuring instruments. These supplies are crucial at different stages of production and finishing. Though the exact number of businesses in this sector is uncertain, it is estimated that around 200 entrepreneurs are involved in supplying these necessary materials.

The Production Process

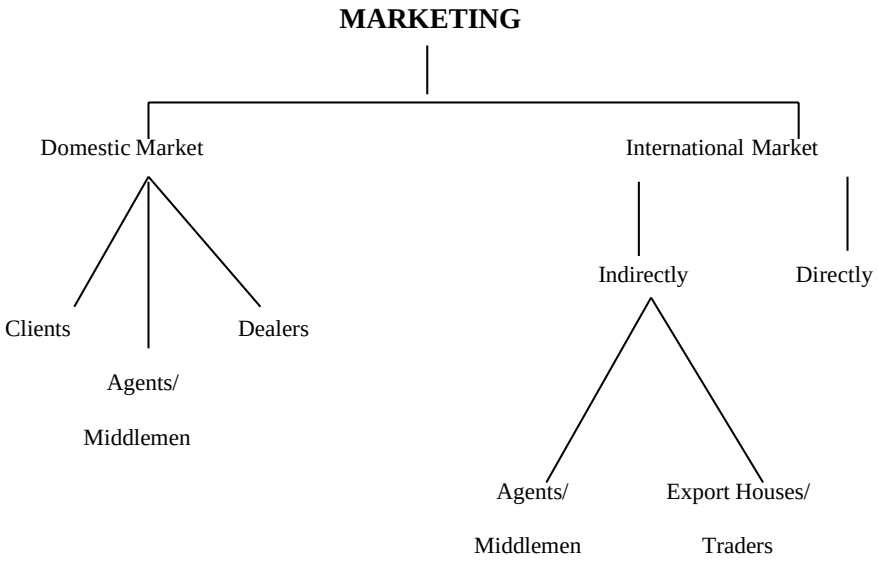
The brass industry in Jamnagar is capable of producing almost any brass part or component, no matter how complex the design. However, before these parts reach the final stage, they undergo several key processes. These processes are crucial to ensuring the parts meet the required specifications and quality standards.

Production Organisation & Producer – Trader Chain in the Jamnagar Brass Parts Industry



[Figure 1.1.1 Chart of Production Organization]

PHASE-V-Market Linkages

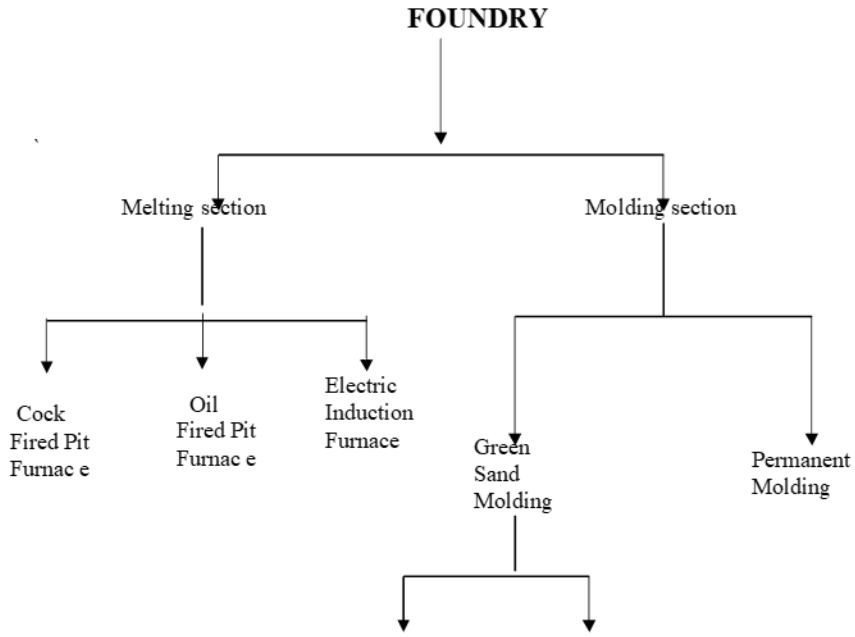


[Figure 1.1.2 Chart of Marketing Linkage]

Foundry

PHASE-II

Marketing Linkage



[Figure 1.1.3 Chart of Marketing Linkage Phase II]

The brass parts industry in Jamnagar, Gujarat, is highly specialized, with most of the machinery needed for manufacturing being locally produced, except for a few small tools and forming dies. The industry's remarkable growth and success, particularly in the export market, can be attributed to the ingenuity of local manufacturers in developing plant and machinery. The industry's success in overcoming international competition, particularly from Japan, has been largely driven by continuous innovation in production techniques, eliminating wasteful practices, and staying updated on the latest developments. Additionally, the sector provides timely post-purchase support to its clients, ensuring consistent production. Local manufacturers have a central role in determining all mechanical processes for brass component production.

Brass components in Jamnagar go through several key manufacturing steps. The process begins with casting, where both local and imported, brass scrap is used to create brass rods of various sizes. These rods are then wire-drawn to ensure a smooth surface before being fed into turning machinery. Turning transforms the rods into parts, followed by threading for components that require threads. After threading, parts may undergo drilling, grinding, and slotting, depending on the specifications.

These operations may not always follow a fixed sequence and can be adjusted based on the requirements of each part. After processing, parts are inspected for defects, with any damaged pieces discarded. Packaging is done according to the type of part, using units such as dozens, kilograms, or pieces.

The brass parts industry in Jamnagar is one of the largest in India, producing around 70% of the nation's machined brass components.[100] The products manufactured here cater to a wide range of industries, including electrical, automotive, building hardware, timepieces, toys, and more. Common products include electrical components like cable glands and fuse parts, automotive parts such as battery terminals and carburettor components, and various building hardware items like door hinges and locks. The diversity of products extends to items like pens, bicycle parts, and surgical instruments, with the industry producing thousands of different types of brass components.

These components are used in sectors ranging from maritime and aerospace to agriculture and precision engineering. The Jamnagar industry primarily produces machined parts, with very few brass sheet metal or cast components. Each day, around 280 to 300 metric tonnes of brass scrap are recycled, contributing to the region's robust manufacturing ecosystem.

However, the industry faces challenges, particularly due to increasing competition from international markets, such as China, Taiwan, and Germany. The liberalization of the Indian economy has intensified cost-based competition, which has impacted the growth of the domestic market. Many companies in Jamnagar have struggled to keep up with changing market dynamics, and some have even been forced to shut down due to declining demand. Despite this, the brass parts sector remains integral to various industries, even as it adapts to new global competition.

The raw materials for Jamnagar's brass components come primarily from imported brass scrap, though some materials are sourced from antique brass and bronze household items. Importing materials accounts for around 90% of the industry's raw material needs, with countries like the United States, Singapore, and European nations being key suppliers. These imported scraps often contain mixed metals, which makes the separation process challenging and can lead to variations in the quality of the final products. Maintaining the correct 60:40 copper-to-zinc ratio in brass is crucial for ensuring high-quality output, but variations in the raw material can cause defects and increase the rejection rate.

In terms of manufacturing equipment, Jamnagar's brass component factories use a variety of machinery, including wire drawing, slotting, turning, threading, and milling machines. The choice of machinery depends on the type of products being made and the specific processes required. While there is no standardized production method, most brass parts undergo several key processes like turning, threading, and grinding to meet the necessary specifications. This versatility in machinery and processes allows the industry to produce a wide range of high-quality brass components that cater to different markets and sectors.

(After Casting)

↓

Drawing/Shaving

↓

Turning/Cutting

↓

Drilling

↓

Threading

↓

Finishing

↓

Plating

[Figure 1.1.4 Chart of Manufacturing Process]

Jamnagar is well-known for its customized machines, with skilled experts and mechanics able to replicate imported machinery or machinery from renowned companies. These machines, which can cost crores, are replicated for just a few lacs and are made available throughout the area. They are often modified to meet specific task requirements, offering flexibility in operations, which is a major advantage for the Jamnagar brass components cluster. Most businesses in the area use these specialized machines.

The production process in Jamnagar has largely remained traditional for the past 50 years, with little change in processes such as melting, machining, polishing, and plating. The foundries lack automated machinery, pressure die-casting machines, temperature control systems, and electropolishing equipment, which leads to challenges like dimensional distortions, pinholes, shrinkage, and other defects. As a result, the rejection rate is high, and a significant amount of recycled parts are used. Many machining processes could be reduced or avoided, such as turning large cast rods to create smaller screws, a time-consuming process that could be eliminated with new technologies like paste brazing.

Some parts in Jamnagar need highly precise tolerances, like the cycle and car tube valves, which are achieved through manual filing and other labour-intensive methods. This results in high rejection rates due to outdated technology. However, using pressure die-casting could significantly improve precision and eliminate the need for manual processes. Additionally, there is a shortage of tools like micrometers to measure products at the micron level, and some exports have been rejected due to the lack of precision.

The Jamnagar cluster consists of over 10,000 brass parts producers, who benefit from a flexible operating system that allows for specialization. Entrepreneurs can handle both small and large orders, and subcontracting is a common practice. If a business lacks a certain machine, it can outsource the work to another manufacturer. The availability of specialized machinery and skilled operators has driven growth in the region. These products are marketed both within India and internationally. Many businesses have long-term relationships with major companies, such as cycle manufacturers in Ludhiana who work with Jamnagar's cycle tube valve producers.

The products manufactured in Jamnagar, such as automobile parts, bicycle tube valves, building hardware, and sanitary fittings, are exported to various countries, including the Middle East, Europe, and Southeast Asia. While some businesses sell directly to overseas consumers, many rely on agents and traders to manage the exports. Exporters, particularly from New Delhi, Kolkata, and Mumbai, purchase the products and resell them internationally. To succeed in the global market, entrepreneurs need to collaborate, form consortia, and participate in international trade shows to compete on quality and cost. While Jamnagar had a specialized market in Arab and African countries, competition from countries like China and Taiwan has intensified, making it essential to focus on quality and price.

Most businesses in Jamnagar are family-owned, with family members handling various roles such as management, marketing, and operations. Few outside professionals are hired, which has led to a lack of innovation and adherence to traditional production methods. The entrepreneurs' limited technical and marketing knowledge is partly due to low educational levels and difficulty with English. Despite the availability of advanced equipment like pressure die-casting machines, many entrepreneurs still struggle to acquire them. The manufacturing processes are often based on imitation, and there is little outside input, particularly in terms of technology. The lack of equipment for measuring and controlling temperature is another issue that businesses face.

Financially, Jamnagar's entrepreneurs have access to sufficient funds, with credit often being extended to customers. Working capital is usually available through local banks, particularly the State Bank of Saurashtra. While the financial systems are up-to-date, many businesses do not seek bank loans for new equipment because the machinery is relatively inexpensive. Working capital is critical, especially due to the high cost of brass and the fast turnover of materials. Export-oriented businesses make good use of export credit resources, but the need for long-term loans is minimal, given the low capital requirements for setting up foundries and plating shops.

The region has an abundance of skilled labour, and workers are typically hired through a sign-up process at factory gates. While some tasks are still performed manually, there are few engineers employed in these businesses, which contributes to the technological stagnation of the cluster.

The lack of skilled engineers is a significant issue, as the businesses have maintained a family-oriented structure, which prevents the hiring of experienced professionals. The absence of training institutions or R&D centres is another hurdle, as employees mainly learn on the job or by observing others.

Jamnagar's industrial infrastructure is spread across several areas, including Shankar Tekri, Patel Colony, M.P. Shah Udyognagar, and Digvijay Plot Area, with industrial estates developed by the Gujarat Industrial Development Corporation (GIDC). These estates provide land, water, and power to support the growing industry. Despite this, the area faces challenges like frequent power outages and poor road conditions, which can hinder productivity. Despite these challenges, the number of businesses in Jamnagar has increased significantly, from around 1,000 in 1976 to over 4,000 today.

Business Development Services in Jamnagar: Compared to other industrial areas, Jamnagar has not seen significant growth in business development services. The city lacks institutes for design development, testing facilities, research and development (R&D) labs, management training centres, technical schools, or marketing professionals. Business development services usually grow in response to demand, but Jamnagar has not yet experienced this kind of demand.

The requirements of the industrial cluster may not have been accurately predicted, which has led to a lack of growth in these areas. For this reason, greater networking and collaboration between small and medium-sized enterprises (SMEs) in the region are crucial. For example, one potential solution could be establishing a branch of the National Metallurgical Laboratory from Jamshedpur, a leading institution in metallurgy, to support the needs of the local cluster. Additionally, setting up technical training schools and testing facilities could address business demands and support the development of the area.

Other Issues in Business Development: One key issue is the lack of trust between industries, as most operate independently without much communication. Companies are hesitant to discuss problems or future plans, and joint development activities are rare. This isolation has prevented the industries from benefiting from collaboration, mutual learning, and knowledge sharing. Consequently, businesses have missed out on potential productivity gains and innovations. To address these challenges, more emphasis needs to be placed on improving marketing strategies, funding opportunities, and the availability of skilled labour.

OVERVIEW OF FINANCIAL PERFORMANCE

❖ Financial Performance Analysis

Financial performance analysis involves examining and interpreting financial statements to thoroughly assess a company's profitability and financial health. This process helps identify both the strengths and weaknesses of the business by analysing the connections between the balance sheet and the profit and loss statement. Additionally, it aids in forecasting both short-term and long-term performance, and can reveal growth potential. Typically, there are six key steps involved in conducting an effective financial statement analysis:

- Examine the economic traits of the industry
- Understand the company's strategic goals and plans
- Evaluate the reliability and accuracy of the company's financial reports
- Assess the company's current profitability and risk profile
- Develop projected financial statements
- Determine the company's valuation

Financial analyst will carefully review a company's financial statements, including the income statement, balance sheet, and cash flow statement. A widely used method for analyzing financial data is by calculating ratios based on the information in these statements, which can then be compared to those of other companies or to the company's own past performance.

There are two types of financial analysis:

- **Fundamental Analysis**

Fundamental analysis involves using ratios derived from financial statement data, such as earnings per share (EPS), to assess a company's value. By combining ratio analysis with a comprehensive evaluation of the company's economic and financial context, the analyst can determine the intrinsic value of a security. The objective is to calculate a value that investors can compare with the security's current market price to determine if it is undervalued or overvalued.

- **Technical Analysis**

Technical analysis involves analyzing statistical trends derived from trading activity, such as moving averages (MA). It operates on the premise that a security's price already reflects all publicly available information, so the focus is placed on studying price movements and patterns. Rather than examining a security's fundamental characteristics, technical analysis aims to understand market sentiment by identifying recurring trends and patterns in the price data.

❖ Advantages of Financial Analysis

- **Pattern Recognition and Forecasting:** Financial statements reveal trends in earnings, sales, and profits, helping to predict future performance. This data can guide decisions on resource allocation, budgeting, and strategic planning.

- **Real-Time Budget Planning:** Financial statements also aid in creating accurate budget estimates, helping businesses plan for marketing campaigns, expansions, and other expenditures. They ensure that companies can manage their spending effectively and make informed decisions to increase profitability.

❖ Disadvantages of Financial Analysis:

- **Dependence on Market Patterns:** One drawback is that financial analysis often relies on current market conditions, which can fluctuate. Past performance is not always a reliable indicator of future trends, so predictions based solely on historical data can be risky.

- **Single-Time Analysis:** Financial analysis is typically a snapshot of the company's performance at one point in time. It may not provide a long-term view, making it necessary to update the analysis regularly to make informed decisions and ensure accurate forecasting.

❖ Financial Statement

A financial statement is designed to provide details about the resources available to management, how those resources were utilized, and what the company achieved with them. This includes the balance sheet, income statement, and cash flow statement. Data from these core financial statements can be used to calculate financial ratios and perform analyses that examine the company's operations, helping to identify the factors that impact its earnings, cash flow, and risk profile. This analysis typically involves reviewing historical data, with the ultimate goal of gaining insights into the company's financial performance.

Financial analysis is often referred to as the analysis and interpretation of financial statements. It involves examining the relationships between different items in the financial statements to assess the financial strengths and weaknesses of a business. According to Metcalf and Titard, "Analyzing financial statements is the process of evaluating the connections between the various components of the financial statements to gain a deeper understanding of a company and its performance."

They are useful for the following reasons:

- To determine the ability of a business to generate cash, and the sources and uses of that cash.
- To determine whether a business has the capability to pay back its debts.
- To track financial results on a trend line to spot any looming profitability issues.
- To derive financial ratios from the statements that can indicate the condition of the business.
- To investigate the details of certain business transactions, as outlined in the disclosures that accompany the statements.

❖ Four Types of Financial Statements

1. Statement of Financial Position

The Statement of Financial Position, also known as the Balance Sheet, provides a snapshot of an entity's financial status at a specific point in time. It consists of three key components:

- **Assets**: Resources owned or controlled by the business, such as cash, inventory, property, and equipment.
- **Liabilities**: Obligations the business owes to others, including debts like loans or amounts payable to creditors.
- **Equity**: The residual value belonging to the business's owners, representing the capital remaining after subtracting liabilities from assets. Equity reflects the difference between total assets and total liabilities.

2. Income Statement

The Income Statement, also referred to as the Profit and Loss Statement, outlines a company's financial performance by showing its net profit or loss over a defined period. The Income Statement includes two main components:

- **Income**: The earnings generated by the business during the period, such as sales revenue, dividend income, and other sources of income.
- **Expense**: The costs the business incurs during the period, such as salaries, depreciation, rent, and other operational expenses. Net profit or loss is determined by subtracting expenses from income.

3. Cash Flow Statement

The Cash Flow Statement shows the changes in a company's cash and bank balances over a specific period. The cash flow movement is categorized into three main sections:

- **Operating Activities**: Cash flow related to the core operations of the business.
- **Investing Activities**: Cash flow from buying and selling assets, excluding inventories, such as purchasing or selling a factory or equipment.
- **Financing Activities**: Cash flow associated with raising or repaying capital, including activities related to share capital, debt, and payments of interest and dividends.

4. Statement of Changes in Equity

The Statement of Changes in Equity, also called the Statement of Retained Earnings, outlines the changes in owners' equity over a given period. These changes are influenced by several factors:

- **Net Profit or Loss**: The profit or loss for the period, as reported in the income statement.
- **Share Capital**: The issuance or repayment of share capital during the period.
- **Dividend Payments**: Dividends paid to shareholders.
- **Gains or Losses in Equity**: Any gains or losses that are directly recognized in equity, such as revaluation surpluses.

❖ Purpose OF Financial Statement

The following are the main purpose of the analysis of financial statements:

- To assess the firm's ability to generate earnings.
- To evaluate the long-term liquidity of the company's funds.
- To assess the firm's solvency.
- To determine the company's capacity to take on debt.
- To make informed decisions about the firm's future potential.
- To evaluate the efficiency of the company's operations.

❖ Objectives of Financial Analysis

- Reviewing the company's performance over past periods.
- Assessing the current financial position.
- Forecasting the profitability trends.
- Forecasting financial failure.

❖ Limitation of Financial Analysis

- Not a Substitute of Judgement
- Based on Past Data
- Problem in Comparability
- Reliability of Figures
- Various methods of Accounting and Financing
- Change in Accounting Methods
- Changes in the Value of Money
- Limitations of the Tools Application for Analysis
- No Assessment of Managerial Ability
- Change of Business Condition

❖ Techniques/ Tools Financial Performance Analysis

Financial performance analysis can be conducted using various tools and techniques of financial analysis.

- **Accounting techniques**

  These are also referred to as financial techniques. Several accounting methods, such as Comparative Financial Analysis, Common-size Financial Analysis, Trend Analysis, Fund Flow Analysis, Cash Flow Analysis, CVP Analysis, Ratio Analysis, and Value Added Analysis, can be employed for financial analysis purposes.

The primary techniques used in this context include:

1. **Ratio Analysis**
2. **Trend Analysis**
3. **Correlation Analysis**
4. **Regression Analysis – Time Series Analysis**
5. **DuPont Analysis**
6. **Comparative Balance Sheet Analysis**

1 Ratio Analysis

Ratio analysis is a widely used tool for evaluating a company's financial health and performance. Ratios show the relationship between two or more financial figures and are commonly used to highlight important connections between items on a balance sheet, income statement, budget, or other financial records. This analysis helps identify a company's strengths and weaknesses compared to others in the same industry and shows if its financial situation is improving or declining over time. Ratio analysis provides valuable insights for investors, creditors, and analysts, enabling them to review past performance, understand the current financial position, and make informed predictions about future results.

Ratios can be classified into four broad groups on the basis of items used:

A. Liquidity Ratio

B. Solvency Ratio

C. Activity Ratio

D. Profitability Ratio

A. Liquidity Ratio

Liquidity ratios assess a company's capacity to fulfil its short-term debt obligations, indicating if it can pay off immediate liabilities as they become due.

Liquidity ratios are calculated by dividing cash and other liquid assets by short-term borrowings and current liabilities. These ratios indicate how many times cash and liquid assets can cover short-term debts. If the ratio is above 1, it means the company can fully meet its short-term obligations. A higher liquidity ratio provides a stronger safety margin, showing the company is better positioned to handle current liabilities. Ratios above 1 generally reflect good financial health and a lower risk of financial trouble.

The cash cycle is crucial for understanding liquidity ratios, as it reflects how cash moves through a company's operations. Cash is often tied up in finished goods, raw materials, and trade receivables. A company only receives cash once inventory is sold, invoices are issued, and payments are collected. This cash tied up in the cycle is known as working capital, and liquidity ratios assess the balance between current assets and current liabilities. Essentially, a company should be able to convert its short-term assets into cash, which is what liquidity ratios aim to measure.

The following are the liquidity ratios used in this analysis:

a. Current Ratio

b. Quick Ratio

c. Absolute liquidity Ratio

a. Current Ratio

The current ratio, also known as the working capital ratio, is found by dividing current assets by current liabilities. It shows the company's ability to cover short-term obligations. A ratio below 1 may signal liquidity issues, while a very high ratio could mean excess cash or inventory that might be better invested. A ratio between 1.2 and 2.0 is generally considered adequate. Low current ratios (below 1) can suggest difficulty in meeting obligations, but strong operating cash flow can sometimes support a lower current ratio.

Current Ratio = Current Asset / Current Liabilities

b. Quick Ratio

The quick ratio measures a firm's ability to meet short-term obligations as they come due. Quick assets, or liquid assets, are current assets that can be quickly converted into cash, excluding inventory and prepaid expenses. The quick ratio is calculated by dividing quick assets by quick liabilities.

Quick ratio = Quick Assets / Quick Liabilities

c. Absolute liquidity Ratio

The absolute liquid ratio excludes accounts receivable from liquid assets to account for potential delays in collection. This ratio is most effective when analyzed alongside the current and quick ratios.

Absolute Liquid ratio = Cash and Bank Balance / Current Liabilities.

B. Solvency Ratio (Leverage Ratio)

Financial analysts often focus on a firm's mix of debt and equity. Solvency refers to a company's capacity to fulfil its long-term obligations. Solvency ratios, like the Debt-Equity Ratio and Proprietary Ratio, assess a firm's ability to cover fixed interest, costs, and repayment schedules for its long-term debts.

The following are the Leverage ratios used in this analysis:

a. **Total Debt Equity Ratio**
b. **Long Term Debt to Shareholders Net Worth**
c. **Fixed Asset Ratio**
d. **Fixed Assets to Net Worth Ratio**
e. **Proprietor Ratio**

a. Total Debt Equity Ratio

Many financial analyses are interested in the relative use of debt and equity in the firm. The term 'solvency' refers to the ability of a concern to meet its long-term obligations. Accordingly, long-term solvency ratios indicate a firm's ability to meet the fixed interest and cost and repayment schedule associate with its long-term borrowings. (i.e.) Debt Equity Ratio, Proprietary Ratio, etc….

Total Debt Equity Ratio= Total Debt / Equity

b. Long Term Debt to Shareholders Net Worth

The long-term debt to equity ratio is a leverage ratio that compares a company's total long-term debt to its shareholders' equity. This ratio helps determine the level of debt the company is using. A higher ratio indicates that the company is relying more on debt for financing.

Long Term Debt to Shareholders Net Worth = Long Term Debt / ShareholdersFund

c. Fixed Asset Ratio

The Fixed Assets Ratio is a long-term solvency ratio calculated by dividing a company's total fixed assets by its long-term funds. It indicates how much of the company's fixed assets are financed by each unit of long-term funds.

Fixed Asset Ratio= fixed Assets / Capital Employed

d. Fixed Assets to Net Worth Ratio (Fixed Asset to Proprietors Fund Ratio)

The Fixed Assets to Net Worth ratio shows a company's financial strength. It is calculated by dividing the company's fixed assets by its equity capital, which is the money invested by shareholders. If the ratio is greater than 1, it means that some of the company's assets have been financed through debt.

Equity Capital Ratio = Fixed Assets/ Shareholders Fund

e. Proprietary Ratio

The Proprietary Ratio compares shareholders' funds to total assets. It is calculated by dividing shareholders' funds by total assets. This ratio shows the owner's contribution to the overall value of the company's assets.

Proprietary ratio = Shareholders fund / Total assets.

C. ACTIVITY RATIOS/ TURNOVER RATIOS

These ratios assess how effectively a business utilizes its resources and components of total assets. They measure how efficiently assets are managed, with efficiency reflected in how quickly assets are converted into sales. A higher turnover rate indicates better management efficiency.

The following are the activity ratios in this analysis:

a. **Inventory Turnover Ratio**
b. **Inventory Holding Period**
c. **Fixed Asset Turnover Ratio**
d. **Current Asset Turnover Ratio**
e. **Total Asset Turnover Ratio**
f. **Capital Turnover Ratio**
g. **Working Capital Turnover Ratio**

a. Inventory Turnover Ratio

The Inventory Turnover Ratio measures the relationship between the cost of goods sold and average inventory. It indicates how quickly inventory is sold and turned into sales. A high inventory turnover ratio typically reflects efficient inventory management, as the stock is sold more frequently, requiring less capital to finance the inventory. It shows how many times a company's inventory is sold and replaced over a certain period. The ratio is calculated as follows:

Inventory Turnover Ratio = Net sales / Inventory

b. Inventory Holding Period

The Inventory Holding Period indicates the average number of days a business holds its inventory. To calculate it, divide inventory by the cost of sales, then multiply the result by 365 to get the holding period in days, or by 12 for the holding period in months.

Inventory Holding Period = 365 / Inventory Turnover Ratio

c. Fixed Assets Turnover Ratio

It shows the relationship between net sales and fixed assets, measuring how effectively the company's management generates sales from its fixed asset base.

The ratio shows whether the company is over-investing in assets to generate sales and measures the productivity of these assets. It reveals how much the investment in fixed assets contributes to sales, especially when compared to the previous year. The ratio is calculated as follows:

Fixed Asset Turnover Ratio = Net Sales / Net Fixed Assets

d. Current Assets Turnover Ratio

The Current Assets Turnover Ratio shows the relationship between current assets and sales. In other words, it measures how efficiently a company uses its assets to generate sales. It is calculated as follows:

Current Asset Turnover ratio = Net Sales / Current Assets

e. Total Assets Turnover Ratio

The Total Assets Turnover Ratio measures the value of a company's sales or revenue in relation to the value of its assets. This ratio is often used to gauge how efficiently a company is utilizing its assets to generate revenue.

Total Assets Turnover ratio = Net Sales / Total Assets

The Capital Turnover Ratio measures how efficiently an organization uses its capital in the business. It is calculated as:

f. Capital Turnover Ratio

Capital turnover measures an organization's efficiency in using the capital invested in the business. It is calculated as:

Capital Turnover Ratio = Sales / Capital Employed

g. Working Capital Turnover Ratio

The Working Capital Turnover Ratio shows the relationship between working capital and sales, reflecting how working capital changes with sales fluctuations. This ratio measures how efficiently net working capital is used, indicating how many times it is turned over in a year. It is a useful indicator of over-trading or under-trading. The formula for calculating the working capital ratio is as follows:

Working capital turnover ratio = Net sales / Working Capital

D. PROFITABILITY RATIOS

To draw meaningful conclusions, the profitability ratios for this quarter should be compared to those of the same quarter in previous years. Profitability ratios measure a business's performance, reflecting the outcomes of business activities and allowing an assessment of overall efficiency. The profitability ratios used in this analysis are as follows:

a. **Net profit ratio**
b. **Gross Profit Ratio**
c. **Operating Ratio**

a. Net Profit Ratio

The Net Profit Ratio shows the relationship between net profit (after taxes) and sales. It is calculated by dividing net income after tax by net sales for the period, indicating profit earned per rupee of sales. This ratio reflects the remaining profit after all production, administration, financing costs, and taxes are deducted from sales, making it a strong measure of overall performance—especially when paired with an assessment of working capital usage. It is often tracked over time to assess performance trends and to compare a business's results with competitors. The Net Profit Ratio reveals the profit generated from each rupee of sales, covering both direct and indirect operating costs.

Net Profit Ratio = Net Profit / Net Sales * 100

b. Gross Profit Ratio

The Gross Profit Ratio measures the profit made on products without including indirect costs, indicating gross profit per rupee of sales. This ratio shows the profit margin from selling products or services before deducting selling and administrative expenses, reflecting the company's ability to produce goods cost-effectively. Tracking this ratio over time can reveal whether a business consistently provides products that customers are willing to pay for at a reasonable price. A declining gross profit ratio may suggest reduced sales prices, increased production costs, or a shift to lower-profit items.

Gross profit ratio = Gross Profit / Net Sales * 100

c. Operating Ratio

The Operating Ratio measures a company's management efficiency by comparing the cost of goods sold to net sales. It indicates how well the company controls costs while generating revenue. A lower operating ratio suggests greater efficiency in revenue generation.

Operating Ratio = Cost of Goods Sold / Net Sales ×100

2. TREND ANALYSIS

Trend analysis involves gathering data and identifying patterns within it. While commonly used to forecast future events, trend analysis can also help estimate uncertain past occurrences, like the probable number of ancient kings between two dates based on historical data about average reign durations. When predicting future events, it's important to remember that past influencing factors may not impact future data in the same way. Therefore, extrapolating from historical trends alone may not provide an accurate forecast, and additional research should support trend analysis for reliable predictions.

Trend analysis is a method of examining current trends to forecast future ones, functioning as a type of comparative analysis. It often includes assessing if a trend, like growth in a specific market sector, will persist or if a trend in one area might influence another. Although this analysis may require extensive data, there is no assurance that its predictions will be accurate.

❖ Advantages of Trend Analysis:

- **Inter-Firm Comparison Potential:** Trend analysis enables effective comparisons between two or more firms over time and can be measured against the industry average. This helps gauge a firm's strengths or weaknesses relative to similar firms in the industry.

- **Decision-Making Value:** Analysing trends in percentages is more impactful than using absolute figures, supporting management in informed decision-making.

- **Aid for Comparative Analysis:** Trend analysis is highly useful in comparing financial data over time, assessing a firm's performance, and assisting management in planning for the future.

- **Liquidity and Solvency Assessment:** It provides insights into a firm's short-term liquidity and long-term solvency through relevant financial trend ratios.

- **Profitability Insight:** It also helps evaluate a firm's profitability over time, using financial ratios like Operating Ratio, Net Profit Ratio, and Gross Profit Ratio.

❖ Disadvantages of Trend Analysis:

- **Choosing a Base Year:** Selecting an appropriate base year is challenging, as it ideally should be a normal year. Without a suitable base, the analysis may lose value.

- **Consistency Issues:** Following consistent accounting policies is difficult, especially with evolving accounting practices, impacting trend reliability.

- **Limitations During Inflation:** Trend analysis is less reliable during inflation, as changes in price levels may distort results.

- **Trend Percentage Calculation:** Typically, one year's statement is set as the base, with each base item marked at 100. Each item in subsequent years is divided by the base year's corresponding figure, giving trend ratios in percentage form.

3. DUPONT ANALYSIS

DuPont analysis, also known as the "DuPont identity," is a widely used performance measurement method developed by the DuPont Corporation. This technique breaks down the components driving Return on Equity (ROE), enabling investors to examine specific performance indicators in detail rather than relying on a general evaluation.

Equity investors often consider Return on Equity (ROE) to assess if a company is providing a good return on shareholders' investments. However, relying solely on ROE may not provide a complete picture; DuPont analysis offers a deeper insight into the components of ROE, giving a clearer understanding of how returns are generated. The DuPont formula can be calculated as follows.

ROE = (Net Income / Sales) * (Sales / Assets) * (Assets / Shareholder's Equity)

In this equation, ROE is divided into three components: net profit margin, which shows how much profit the company makes from sales; asset turnover, which measures how efficiently the company utilizes its assets; and the equity multiplier, indicating the level of leverage.

If ROE rises due to an increase in net profit margin or asset turnover, it's a positive sign for the company. However, if the ROE increase is driven by a higher equity multiplier, it might be a concern, as it suggests that the company's ROE is being boosted by additional leverage.

❖ Limitations of DuPont Analysis

• It does not factor in the cost of capital.

• The DuPont model may not be as relevant for industries like investment banking, where its sub-elements are less meaningful. One way to address this is by creating less directly meaningful elements.

• The DuPont identity is an accounting formula, meaning it's true by definition. Since it relies on accounting data, companies may manipulate the numbers to conceal short-term weaknesses, even though this is unethical.

• "Garbage in, garbage out": the accuracy of the output depends on the quality of the input data.

4. CORRELATION ANALYSIS

Correlation analysis is a statistical method used to examine the strength and direction of the relationship between two or more variables. Variables are considered correlated when changes in one variable are associated with changes in another. This analysis is typically conducted when a researcher aims to identify potential associations between variables. The steps involved in correlation analysis include:

• Identifying whether a relationship exists and measuring it (using the Coefficient of Correlation).

• Testing the significance of the relationship.

• Determining any cause-and-effect relationship, if applicable.

In correlation analysis, two types of variables are involved: dependent and independent. The goal of this analysis is to determine whether changes in the independent variable lead to changes in the dependent variable. The question then arises: why is it important to study correlation? The study of correlation is highly valuable in practical life for the following reasons: Correlation analysis helps measure the degree of relationship between various variables, such as income and expenditure or demand and sales, by representing the relationship in a single figure.

• Once the relationship between variables is determined, the value of an unknown variable can be estimated if the value of another variable is known. This can be achieved through regression analysis.

• For manufacturing firms, correlation analysis assists in estimating the price, cost, and sales of products based on other related variables.

• It aids in understanding economic behaviour by helping economists identify critical variables that influence other economic factors.

• Correlation analysis is widely used but can be misinterpreted, as it only measures the strength of linear relationships and doesn't necessarily indicate causality between the variables.

❖ Advantages of Correlation Analysis

• Correlation studies can be conducted on variables that cannot be manipulated, making it useful when experimental methods are impractical or unethical.

• It helps identify the presence or absence of a relationship between two variables, which can guide further experimental research to explore the relationship in more depth.

❖ Limitations of Correlation Analysis

• Correlation analysis can only be used when both variables are measurable on a scale.

• Correlation research cannot establish cause and effect, as it is unclear whether one variable causes the other, or if an unknown factor is responsible for the correlation.

5. Regression Analysis

Regression analysis is a statistical technique used to estimate the relationship between a dependent variable and one or more independent variables. It can assess the strength of this relationship and model future trends. There are various types of regression analysis, such as linear, multiple linear, and nonlinear, with simple linear regression being commonly used.

The equation for simple linear regression is:

$Y = a + bX$

Where:

Y = Dependent Variable

X = Independent Variable

a = Intercept

b = Slope

6. COMPARATIVE BALANCESHEET

A comparative balance sheet examines the trend of specific items and calculated figures across two or more balance sheets of the same business at different points in time. It typically consists of two columns for each balance sheet item: one column represents the current year's financial position, while the other shows the previous year's financial position. This format helps investors and stakeholders easily compare and analyze the company’s financial performance over the past year.

OVERVIEW OF FINANCIAL COMPETENCY

Introduction to Financial Competitiveness:

Financial performance is a critical tool for evaluating the effectiveness of various banks in areas like profitability, operational efficiency, and financial stability. Stakeholders are particularly interested in assessing the financial health of a company, such as those in the Brass Industry, to gain insights into its overall performance. Financial statements play a crucial role in fundamental stock analysis and investment research, helping individuals make informed judgments about a company's financial strength and future prospects. Finance is often referred to as the "science of money" because of its central role in business operations.

Financial performance can be understood subjectively as a measure of how well a company utilizes its assets from core business activities to generate revenue. This measure is also used as a general indicator of a firm's overall financial well-being over a given period, allowing comparisons between similar firms in the same industry or across different industries. The financial performance of a business is typically expressed through the profits and losses over a specified time frame. By evaluating financial performance, decision-makers can assess the effectiveness of business strategies and activities in monetary terms.

There are various ways to measure financial performance, with common metrics including revenue, operating income, cash flow from operations, and total unit sales. Investors or analysts might also delve deeper into financial statements to identify trends in margins, growth rates, or reducing debt levels. Ultimately, financial performance is a reflection of how a company’s policies and operations contribute to its return on investment, return on assets, and other value metrics.

The financial performance of a firm is influenced by two key factors: risk and profitability. These factors jointly determine the company’s value. Decisions that increase risk tend to decrease a firm’s value, while decisions that boost profitability generally increase its value. The relationship between profit maximization and wealth maximization has been a subject of much debate, but it is clear that both are interconnected and impact firm performance.

To evaluate a company's financial performance, analysts often rely on several key ratios. These include:

1. **Profitability Ratios**
2. **Liquidity Ratios**
3. **Debt-Equity Ratios**

These ratios, along with other financial metrics, help assess the financial position of a company. The balance sheet provides a snapshot of the company's financial position at a specific point in time, while the profit and loss account reflects performance over a given financial year. In India, where analysts depend on audited financial statements, the company's performance is typically evaluated based on these financial documents.

Financial competency, on the other hand, refers to the ability to manage one's personal finances effectively, make informed decisions, and achieve financial security. It involves understanding key financial principles, managing resources wisely, and utilizing financial tools to meet personal financial goals.

❖ Components of Financial Competency:

1. Financial Knowledge:

- Understanding financial concepts, such as compound interest, inflation, and diversification
- Knowing how to read financial statements and understand financial ratios
- Familiarity with financial products, such as stocks, bonds, and mutual funds

2. Financial Planning:

- Setting short-term and long-term financial goals
- Creating a budget and sticking to it
- Developing a plan to achieve financial goals, such as saving for retirement or paying off debt

3. Budgeting:

- Tracking income and expenses
- Categorizing expenses and identifying areas for reduction
- Creating a budget that accounts for all necessary expenses and savings

4. Saving:

- Building an emergency fund to cover unexpected expenses
- Saving for long-term goals, such as retirement or a down payment on a house
- Understanding the importance of saving and making it a priority

5. Investing:

- Understanding different types of investments, such as stocks, bonds, and mutual funds
- Knowing how to evaluate investment opportunities and make informed decisions
- Diversifying investments to minimize risk

6. Debt Management:

- Understanding different types of debt, such as credit card debt and mortgages
- Knowing how to manage debt effectively, such as paying off high-interest debt first
- Avoiding debt traps and understanding the importance of credit scores

7. Financial Risk Management:

- Understanding potential financial risks, such as job loss or medical emergencies
- Having a plan in place to mitigate these risks, such as insurance or an emergency fund
- Knowing how to evaluate and manage financial risk

8. Financial Analysis:

- Understanding financial statements and ratios
- Knowing how to evaluate financial performance and make informed decisions
- Using financial analysis to achieve financial goals

9. Financial Goal-Setting:

- Setting specific, measurable, achievable, relevant, and time-bound (SMART) financial goals
- Breaking down large goals into smaller, manageable steps
- Creating a plan to achieve financial goals and tracking progress

10. Financial Discipline:

- Avoiding impulse purchases and staying committed to financial plans
- Understanding the importance of delayed gratification and long-term thinking
- Making sacrifices in the short-term to achieve long-term financial goals

❖ Benefits of Financial Competency:

1. Financial Stability: Financial competency helps you achieve financial stability by managing your finances effectively. This reduces financial stress and anxiety.

2. Wealth Creation: Financial competency helps you grow your wealth by making informed investment decisions and managing your finances effectively.

3. Improved Credit Score: Financial competency helps you manage your debt effectively, which improves your credit score.

4. Increased Confidence: Financial competency gives you confidence in your financial decisions and planning for the future.

5. Better Financial Decision-Making: Financial competency helps you make informed decisions about investments, insurance, and other financial products.

6. Reduced Financial Stress: Financial competency reduces financial stress and anxiety by helping you manage your finances effectively.

7. Improved Quality of Life: Financial competency improves your quality of life by helping you achieve financial goals and enjoy financial freedom.

8. Increased Peace of Mind: Financial competency gives you peace of mind by knowing that you're prepared for unexpected events and have a plan in place.

9. Better Work-Life Balance: Financial competency helps you achieve a better balance between work and personal life by reducing financial stress and anxiety.

10. Increased Financial Independence: Financial competency gives you financial independence by helping you achieve financial goals and enjoy financial freedom.

❖ Limitations of Financial Competency:

1. Complexity:

- Financial concepts and products can be difficult to understand, making it challenging for individuals to make informed decisions.
- Complexity can lead to analysis paralysis, causing individuals to delay or avoid making financial decisions.

2. Emotional involvement:

- Financial decisions are often emotional, and individuals may make impulsive or biased decisions based on personal feelings rather than objective analysis.
- Emotional involvement can lead to poor financial decisions, such as buying high and selling low in investments.

3. Limited knowledge:

- Individuals may not have the necessary knowledge or expertise to navigate complex financial situations, leading to potential mistakes or missed opportunities.
- Limited knowledge can lead to a lack of confidence in making financial decisions.

4. Biases and assumptions:

- Individuals may hold biases or make assumptions about financial markets, investments, or economic trends, which can lead to suboptimal decisions.
- Biases and assumptions can lead to a lack of diversification in investments or a failure to consider alternative perspectives.

5. Time constraints:

- Managing finances requires time and effort, which can be challenging for individuals with busy schedules or multiple responsibilities.
- Time constraints can lead to procrastination or neglect of financial planning and decision-making.

6. Information overload:

- The abundance of financial information available can be overwhelming, making it difficult for individuals to discern relevant and accurate information.
- Information overload can lead to analysis paralysis or poor financial decisions based on incomplete or inaccurate information.

7. Conflicting goals:

- Individuals may have competing financial goals, such as saving for retirement while paying off debt, which can create challenges in allocating resources effectively.
- Conflicting goals can lead to a lack of progress towards achieving financial objectives.

8. External factors:

- Financial markets, economic conditions, and regulatory changes can be unpredictable and outside of an individual's control, impacting financial decisions.
- External factors can lead to a lack of confidence in making financial decisions or a sense of powerlessness in achieving financial goals.

9. Personal relationships:

- Financial decisions can be influenced by personal relationships, such as family or friends, which can lead to conflicts or biased decisions.
- Personal relationships can lead to a lack of objectivity in financial decision-making.

10. Self-discipline:

- Financial competency requires self-discipline and the ability to stick to long-term plans, which can be challenging for individuals with short-term focus or impulsive tendencies.
- Self-discipline is essential for achieving financial goals and avoiding financial pitfalls.

REFERENCES

1. Paul T. Craddock, Journal of Archaeological Science, Volume 5, Issue 1, March 1978, Pages 1-16
2. John Zronik, “Metals Shaping our World”, Published By Crabtree Publishing Company, Canada, 2005, page 7
3. Brady, George S., Henry R. Clauser, and John A. Vaccari. "Brass." In Materials Handbook, 14th ed. New York: McGraw-Hill, 1997, Pages- 13
4. Copper Development Association, “Brass in Focus”, Pub 177, Section- 7, May/June-2004, Page 1-3
5. William Benham and Richard K.Meade, “The Technical Analysis of brass and the Non-Ferrous Alloy”, University of California, 1911, pages 180 -189
6. S.W.Fortune: Structure and Properties of Engineering Alloys, 2nd Edition, McGraw-Hill, 1993, 243.
7. John Zronik, “Metal Shapping our world”, Published By Crabtree Publishing Company, Canada, 2005, page 10
8. Brott, Clark W., “How Stone Became Tools and Weapons”, Edited by Richard F. Pourade, Coploy Press, 1966, pp. 141 – 179.
9. Chernykh, Evgenil Nikolaevichs,“Copper the Ancient Metal”, Cambridge University Press, 1992, 335 p.
10. William Benham Price and Richard K. Meade, “The Technical Analysis of Brass and the Non-Ferrous Alloys”, University of California, 1911, pages 180 – 189
11. Goran Burenhult, “People of the Stone Age”, Cambridge University Press, 1993, pages 119 – 121
12. Thomas M. Leonard, “Encyclopedia of the Developing World”, Published By Routledge Taylor And Francis Group, New York, Volume-3, 2006, pp. 1288.
13. Mel M. Schwartz, “Encyclopedia of Materials, Parts and Finishes”, 2nd ed. CRC Press, Florida, 2002, page 171.

14. William Leonard Langer, “An encyclopedia of world history: ancient, medieval and modern”, 4th addition, the university of Michigan, Published by Harrap Press, 1968, pages:3,9,27

15. AJ Wilson, “The Living Rock: The Story of Metals since Earliest Times and Their Impact on Civilization”, Woodhead publishing, 1994, pages:25,34

16 Bertie Webster Smith, “Sixty Centuries of Copper”, Issue-69(Copper Development Association), The University of Michigan, Hutchinson of London, 1965, pp. 36

17. John Zronik, “Metals Shaping our World”, Published By Crabtree Publishing Company, Canada, 2005, page 10

18. Ann Clyburn Gunter, “The Bronze Age”, University Museum of Archeology and Anthropology, University of Pennsylvania, 1991, pages:1-18

19. John M. Coles, A.F. Harding, “The bronze age in Europe: an introduction to the prehistory of Europe”, The University Paperback, USA, 1979, pages:248,278

20. Gunter Joseph, “Copper: its Trade, Manufacture, Use and Environment Statue, edited by Konrad J.A. Kunding, Published by ASM International, USA, 1999, pages 2-5

21. James D. Muhly, “Sources of Tin and the Beginnings of Bronze Metallurgy”, American Journal of Archaeology, Vol.89, No.2, Apr., 1985, pp. 275-291

22. HJ Greenfield, “The Origin of Metallurgy”, Journal of Archeological Science, Volume 26, Issue 7, July-1999, pages 797-808

23. W O Alexander, “A Brief Review of the Development of the Copper, Zinc and Brass Industries in Great Britain”, Murex Review Vol.1, Birmingham, 2002, pages 13-26

24. Provo and Utah, “Copper, Bronze and Brass”, Journal of book of Mormon Studies, Maxwell Institute, 2000, Volume-9, Issue-2, pages: 42-43

25. “Brief History of Brass”, Article of Copper Development Association, U.K., 2004, Pub 117, Section-8, pp. 81

26. Paul V. Hartman, “From Stone Age to copper age”, Norwegian Archeological Review, 1502 – 7678, Volume 32, Issue 2, 2001, Page 113

27. Alan W. Cramb, “A Short History of Metals”, Department of materials science and Engineering, Carnegie Mellon University, U.S., 2002, pages: 43-42

28. Gunter Joseph, “Copper: its Trade, Manufacture, Use and Environment Statue, edited by Konrad J.A. Kunding, Published by ASM International, USA, 1999, pages2-5

29. “Mining and Metallurgy”, Volume 6, Issue-7, American Institute of mining and metallurgical Engineers, University of Virginia, 2003, pages 156-167

30. Gunter Joseph, “Copper: its Trade, Manufacture, Use and Environment Statue, edited by Konrad J.A. Kunding, Published by ASM International, USA, 1999, pages 4-6

31. Phyllis Deane, “The First Industrial Revaluation”, Cambridge University press, 1975, Pages: 4-13

32. Gunter Joseph, “Copper: its Trade, Manufacture, Use and Environment Statue, edited by Konrad J.A. Kunding, Published by ASM International, USA, 1999, pages 3-5

33. Brief History of Brass”, Article of Copper Development Association, U.K., 2004, Pub 117, Section-8, pp.82

34. Joseph R. Davis, “Copper and Copper Alloy”, Copper Development Association Handbook, 1999, pp. 127, 163, 267

35. Gunter Joseph, “Copper: its Trade, Manufacture, Use and Environment Statue, edited by Konrad J.A. Kunding, Published by ASM International, USA, 1999, page 6

36. Copper Suppy and consumption, Published by Copper Development Association, USA, Annual Data, 2009, pages: 6-15

37. Gunter Joseph, “Copper: its Trade, Manufacture, Use and Environment Statue, edited by Konrad J.A. Kunding, Published by ASM International, USA, 1999, page 6

38. Damodar Dharmanand Kosambi, “Ancient India: a history of its culture and civilization”, The University of Machigan, Panthoon Books, 1966, page-26.

39. Indian History ancient India, Pratiyogita Darpan, Upkar Prakashan, 2009, page-22

40. Jasleen Dhamija, “Indian folk art and crafts”, Indiana University, National Book Trust, India, 1970, pages 1 to 9.

41. Rina shrivastava,” Mining and Metallurgy in ancient India”, the University of Michigan, Munshiram Manoharlal Publishers, 2006, pages: 7 -16.

42. Sayed Jafar, “ Mahmud, Metal technology in Medieval India”, Daya Books, 1988, pages: 66 - 67.

43. Sayed Jafar, "Mahmud, Metal technology in Medieval India", Daya Books, 1988, pages:67-69.

44. Jamila Brij Bhushan," Indian Metal ware", All India Handicrafts Board, Ministry of Commerce and Industry, Govt. of India, 1961, page 32

45. http//www.answer.com/topic/brass

46. Arun kumar Biswas," the Primacy of India in ancient brass and zinc metallurgy", Indian Journal of history of Science, Department of metallurgy, Indian Institute of technology, Kanpur – 1995, pages:360- 369.

47. Meera Mukharjee, "Metalcraftsmen of india", Issue-44, Anthropological Survey of India, Govt. of India, 2006, pages:: 63-70

48. http://www.india-

49. http://www.india-

50. Amar Tyagi, "Let's know: Handicrafts of India", Star Publication, U.K., 2008, pages: 16-20

51. Raj Kapila & Uma Kapila, "Economics Development in india", Academic Foundation, Volume-90, 2005, page-78

52. Jasleen Dhamija, "Crafts of Gujarat:Living traditions of india", Mapin, Indiana University, 1985, page:123

53. Man And Environment, Volume-19, issues 1-2, Indian Society for Prihistoric and Quaternary Studies, the University of Michigan, 2008, page:32

54. Benerjee, Manindranath, "On Metal and Metallurgy in ancient India," Published in IHQ3, 1927, pages:121-133

55. Jasleen Dhamija, "Crafts of Gujarat:Living traditions of india", Mapin, Indiana University, 1985, page:124

56. http://www.indianetzone.com/41/metal_craft_gujarat.ht

57. Kumar Suresh Singh, Rajendra Behri Lal, "People of India:Gujarat", Popular Prakashan Pvt. Ltd., 2003, page:599

58. http://www.craftofgujarat.com/showpage.aspx?contentid=50

59. S.P. Kashyap, Indira Hirway, "Dynamic Development in Gujarat", Centre for Development Alternatives, Ahmedabad, 2002, page:189

60. Source -brass-units-seek-government-support/388725

61. Crane and J. Winter, "Copper: Properties and alloying", Encyclopedia of Materials Science and Engineering, Vol 2, M.B.Bever, Ed. Pergamon Press and the MIT Press, 1986, pages:848-855

62. Joseph R. Davic, "Copper and Copper Alloys", ASM International Handbook, 2001, pages:264-277

63 Konrad J.A., "Copper and Brass: Design For Manufacturability", Ph.d. International Copper Association, New York, Mc Graw-Hill Professional,1999, pages:2.65-2.70

64. Journal of the Institute of Metal, Volume-85, The University of Virgina, 1957, pages:9-31

65. Richard Alfred wilkins, "Copper and Copper base Alloy: The Physical and Mechanical Property of copper and its alloys. The University of Wisconsin-Madison, 1943, pages:132-149

66. Joseph R. Davic, "Copper and Copper Alloys", ASM International Handbook, 2001, pages:153-162

67. Konrad J.A., "Copper and Brass: Design For Manufacturability", Ph.d. International Copper Association, New York, Mc Graw-Hill Professional,1999, pages:2.65-2.72

68. David S. Anderson, Bruce D. Craig, "Material data series: Handbook of corrosion data", ASM International, New York, 1995, page:24

69. Metal World, (June-19, 2000)

70. V.B.Bhandari, "Design of Machine elements, Tata McGraw-Hill, 2007, page-43

71. Cost-Effective Manufacturing - Machining Brass, Copper and its Alloys, CDA Publication TN44, 66pp, Oct 1994.

72. Robert B. Ross, "Handbook of Metal Treatments and Testing", Published by Chapman and Hall Ltd., 1977, page-36

73. Walter E. Burton, "Popular science: Brass, the Metal that works with you", Published by Bonnier Corporation, 1970, page:92

74. R Backerjian, 'Tool and Manufacturing Engineers' Handbook', Vol 4 'Design for Manufacturability, Society of Manufacturing Engineers, Dearborn, Michigan, pp11.3-11.5

75. Lesley Cresswell, "Product Design: Resistant Materials Technology", Heineman, U.K., 2003, page-18

brasses/brasses.html

77. Joseph R. Davic, “Copper and Copper Alloys”, ASM International Handbook, 2001, pages:153-162

78. James G. Bralla, “Design for Manufacturability Hand Book”, 2nd edition, McGraw-Hill Professional, 1999, pages:5.61-5.63

79. “Casting Design and Performance”, ASM International, 2009, Page - 31

80. Copper Development Association, “Brass in Focus”, Pub 177, Section-7, May/June-2004, Page 2-9

81. Cost-Effective Manufacturing - Machining Brass, Copper and its Alloys, CDA Publication, TN44, Oct 1994, page-66

82. Gujarat State Gazetteers, (1962): Jamnagar District, Volume-5, Directorate of Govt., Print Stationery and Publications, 1962, page: 323

83. Jamnagar District Profile Booklet (2007), Industries Commissioner at Government of Gujarat, Index Tb, page: 4-11

84. Engineering and Auto Sector Profile (2004-05), Annual Survey of industries, Industries Commissionerat of Gujarat, page:7

85. Dinesh Awasthi,(2007), “A Comprehensive Study on the Dynamics of Industrial Clusters in India”, Published by Entrepreneurship Development of India, pages:3-7

86. Sanjay Pal, (2002), “Diagnostic Study Report of Brass Parts Cluster at Jamnagar”, The Entrepreneurship Development institute of India(EDI), Ahmadabad, pages:13-17

87. Dhawal Maheta (2002), “Entrepreneurial Innovations in Gujarat”, Journal of AI & Society, Springer, London, Pages: 73-88

88. “Industrial Progress and Popular Industries in Jamnagar District, Article Published by Nawanagar Chamber of commerce and industry, 1999, pages:11-12

89. R.A.Mashelker(2006), “Gujarat Innovates”, National Innovation Foundation, Ahmedabad, page:97

90. “Dynamic Business Partner: Innovation Friendly Destination”, Investment & Technology Promotion Division, Ministry of external affairs Government of India, 2009, pages: 36-37

91. “Major Role of GIDC Behind the Development of Brass Part s Industries in Jamnagar, Article Published by Chamber of Commerce and Industry, Jamnagar, 1998

92. www.energymanagementtraining.comfeveriot

93. L.D.Joshi(2006), "Brass Parts Industry in Gujarat", Industries Commissioner at Government of Gujarat,

94. Sanjay Pal(2002), ""Diagnostic Study Report of Brass Parts Cluster at Jamnagar", The Entrepreneurship Development institute of India(EDI), Ahmadabad, pages:14-18.

95. Gangadasbhai Patel, "Present Status of Brass Parts Industries", Article Published by Factory Owner Association-Jamnagar, 2003

96. Indian Engineering Exports-April 2008, Page No.40

97. SIDBI (Small Industries Development Bank of India, (2003), "Setting up a Common Testing Laboratory- Jamnagar Brass Parts Cluster", Vol-1, Issue-3,

98. "Jamnagar Brass Parts Owners rising against chiness tide", Jamnagar News, 23, December-2007

99. Gujarat Port Development, Regional Round Table, Government of Gujarat, 2005,page:17

100. Jamnagar Brass Components News: Keeping the World up to date with Jamnagar Brass Parts Industries, Business Standard, November- 12, 2009

101. Chotai Ushaben : "Entrepreneur - industrialists of Jamnagar brass industry" - M.Phil. Dissertation, Saurashtra University, 1988.

102. Sodha, R. B.: A study of Jamnagar Brass Parts Industries, M. Phil. Dissertation, Saurashtra University, Rajkot.1990

103. Sandesh – Daily News Paper, Rajkot Edition, Rajkot. 21/11/2008

104. Aajkal Daily News Paper, Rajkot Edition, Rajkot.21/11/2008

105. SOAM Study Report- 2006/2005

106. Dr. C.S. Prasad "Implications of W.T.O. an small Enterprises", M. Phill. Dissertation, Saurashtra University,Rajkot.

107. S. K. Sharma: "W.T.O. and some vital issues for S.S.I., Journal of Small Scale Industries, Jan-Mar.,2000. "laghu Udhyog Samachar January March 2000.

108. Raninga Himanshu S., " Impact of Economic reforms on Small Scale Industries of Saurashtra, Ph.D. thesis, Saurashtra University,Rajkot.

109. Dr. Banyani, " The role and performance of Small Scale Industries in India" I.C.F.A.I. journal of Managerial Economics.

110. Mukesh Kumar and Tirupati Mishra, "Source of Technical Efficiency in Indian Small Scale Industries" I.C.F.A.I. journal of applied Economics.

111. Mullat Tesam, "Institutional reform Macro Economics Policy Change and The development of Small Scale Industries in Ethiopia.

112. Suxcust Pernila, "Small Scale Industries, Transaction cost and reform the case of Tanzania", Working Paper Series in Economics and Finance, Stock Home School of Economics.

113. Bhagvan Reddy B., " Export marketing in Small Scale Industries", Southern Economist March 1, 1987.

114. Deshpande, Manohar Uttam Rao, " Small Scae Industrial entrepreneurship in a developing region, (Thesis Submitted to Marathvada University, 1977- 80).

115. balachandran Lokanadham Committee. " Implementation of Industrial Policy resolution", New Delhi, 1956.

116. Basu S. K., " Place and Problems of Small Scale Industries" (Kolkata: A.Mukharjee & Co. Pvt. Ltd. 1957).

117. Upadhyaya D.V., Some aspects of Household and Small Industries with reference to Gujarat, (Thesis submitted to Gujarat University, 1982.

118. Dhar P.N., Lydal, H.P., "The role of Small Enterprises in IndianEconomic development",(Bombay:Asia Publishing House 1991)