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ANALYSIS OF DISRUPTIVE EVENTS IN KEY COMMODITIES IN AEROSPACE AND DEFENSE INDUSTRIES AND INVENTORY OPTIMIZATION

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Abstract

The aviation grade titanium sponge and its alloy makers are few in number. In the times of increased requirements, the makers guarantee to work close to full limit use. In the course of decreased demand the makers battle to stay beneficial. Moreover, the assembling measures for aviation category titanium composites requires huge investments & require extended lead times to attain new limit. The mix of this element regularly brings about an unyielding titanium compound raw material supply chain for the aerospace and defence industry. Simultaneously, aerospace and defence industry experience an assortment of uncommon however troublesome circumstances inside the supply network that influence their crude material necessities. Instances of this problematic occasions incorporate client drop-in demand, producing complexities bringing about rejected material, and lack of planning. To ensure the structure and supplementary part clients from delaying dispatch because of extended lead times crude materials, aerospace and defence industry holds a safety stock of different titanium alloy crude material. This paper presents a numerical methods using a Poisson distribution for titanium alloy inventory and normal distribution for the demand that can be utilized to improve the measure of key titanium strategic crude material clenched by aerospace and defence industry. The chi square goodness of fit test is used to validate the data whether the arrival of events follows the Poisson distribution or not. The calculated value for chi square is 0.711 and the value obtained from table is 3.843 which is greater than the calculated one therefore there is an evidence that arrival of events follows the Poisson distribution. The related numerical calculations were customized into Microsoft Excel making the Strategic crude Material Inventory Calculator which can be used for optimizing the eight titanium alloy material at different service levels (95%, 99.5% etc.).

*Keywords: **- Supply Chain, Aviation, Titanium, Strategic Inventory, Safety Stock, Disruptive Events.***

1. INTRODUCTION

A supply chain network is used to viably fuse suppliers, manufacturing stages, stockrooms, and stores with the goal that item is conveyed and communicated in correct amounts, to the correct location and at the correct time, to limit supply chain framework wide expenses. An organization's supply chain network includes each operation and their associates that takes an item from crude material suppliers and deliver the finished product. Struggle in the present worldwide markets keeps on expanding, organizations have requested more noteworthy productivity from their supply networks. Product entity span keep on shortening, organizations have requested expanded adaptability from their supply chains. As client assumptions have kept on rising, organizations have requested higher assistance involvement from all segments of their supply chain network. Compelling administration of an organization's supply link network had been a critical area to gain a competitive edge for profit making organizations. Stock is a significant concentration in the learning of supply links network and it's a deciding factor of the supply chain frameworks assembling activities may hold stock for a various factor. A hypothetical least degree of in-line stock is important to keep a said process yield. Inventory is likewise procured because of discount & price reduction or quantity of production. This paper emphasizes the utilization of stock to oblige vulnerability in a supply network. Vulnerability in a supply network can result in uncertainty in supply or the uncertainty in demand. Successful administration of stock to oblige the two uncertainties of supply and uncertainties of demand is key for the effective administration of an organization's supply network. Upholding stock conveys self-expense in both working & economical terms. In this manner, the improvement of stock levels can be a vital cause of working excellence both as far as accomplishing the service level and in decreasing in over all expenses [1].

2. PROBLEM IDENTIFICATION

The main problem for the aerospace and defense industry is the vulnerable titanium raw market supply chain frameworks. The titanium alloy producing mills are relatively small in size. The merchandise for these metals has consistently been repeating in character. Throughout times of requirement, metal makers guarantee to work close to full limit usage. Throughout times of diminished demand, metal makers battle to stay productive. Moreover to produce a titanium sponge is the very capital intensive process as it involves many processes start from obtaining TiO_2 powder, then the binder is added, after that, the mixing is done, and granulation is carried out to make the granules for the cathode, then the process of electrolysis is performed in $CaCl_2$ (calcium chloride), to obtain the metallized granules, after that the washing is done and finally we get the titanium sponge the process of obtaining titanium sponge is called K-roll process. As the processes of obtaining the titanium sponge are very tedious and won't allow a quick change in capacity. The above-mentioned factors frequently result in uncertainty in the supply network of the titanium alloy raw material in the aerospace and defense industry. In addition to this, the aerospace and defense industry also have to accommodate the vulnerability in demand. The industry faces different types of troublesome circumstances in the supply network that affects the requirement of the raw material inventory. The commonly observed events are drop-in order by clients, a complication in manufacturing the product leads to wastage/ producing scrap, and some organizational problem like inaccurate planning; demand forecasting; and some strategic, tactical and natural risk involved in procuring raw materials [1]. In order to protect demand getting delayed in deliveries due to lead time required for the raw material, the aerospace and defense industry holds some safety stock/ strategic raw material inventories of the selective titanium alloy which are regularly required and whose lead time is more. This paper focuses on the analysis of the titanium market scenario, the producers of the titanium and their capacity, market share of the titanium in various sectors like defense, commercial aerospace, industrial usage, and India's titanium scenario. Also discusses the mathematical model to optimize the safety stock of the titanium raw material.

Titanium Demand Forecasting: Growing requirement for new domestic aircrafts could drive 5 – 10 percent annual growth in the gross titanium market for the coming few years. The requirement of Titanium for commercial transport airframes will increase 12.1% every year through 2017, forcing yearly requirement in the sector up 78%, according to the top executive at RTI International Metals Inc. Forecast are that in 5 years we will see 40 million pounds of titanium annually provided to today's aero structure requirement. Larger engines built in the years ahead will mean a greater overall demand for titanium, inroads are being made by competing materials, including composites in the lower-temperature areas of the engine where titanium castings and forged blades have reigned. Titanium consumption grew by an impressive 9% between 2016 and 2017 and is projected to increase by 6% y-on-y in 2018 to more than 170kt, partly because of lower and stable prices. Growth seen during this era has come not just from industrial uses, but also from the aerospace sector - now the single-largest use for titanium mill products. World-wide Trends in Industrial Markets. world titanium intake of the economic sector, which incorporates power, desalinization process, automobile and vessel building, is predicted will register 28,112 metric tons last year and nearly heading towards 30,000 metric tons by this year [1]. Customer-affected applications address 50% to 70 percent of the worldwide market interest for titanium outside of aviation. These applications incorporate parts utilized in huge compound handling and metallurgical plants just as in outdoor supplies, car, engineering, clinical, and then some. Modern market development impacted by framework makes up the leftover 30% to 50 percent of the titanium interest. These applications incorporate customary and atomic power generation plants where titanium is employed in condensers and generators, desalinization plants, oil and gas refineries, and plants delivering liquid gas. Different elements remember expanded interest for titanium items for China and Southeast Asia for substance, oil, and gas, energy, and defence ventures. The high requirement in titanium plant, items has lifted Russian sponge creation near the full limit. Titanium sponge stock has diminished worldwide; the most important decrease is within US. [2].

Medical Demand: Titanium has for quite some time been utilized for a wide range of sorts of inserts, however particularly those related to hip, knee, spine, shoulder, and elbow surgeries. Generally, the demand has been extremely high for these sorts of inserts since they are vigorously identified with infections identified with maturing, including osteoarthritis, rheumatoid joint inflammation, and numerous other degenerative sicknesses that the maturing generation populace is progressively experiencing. It is this maturing of the U.S. furthermore, total populace (generally, the clearly the larger part of implant procedures are done in the United States and Europe, however, that is changing with expanded GDP development in non-industrial countries) that has been viewed as the essential factor pushing insert demand. Demand in titanium will stay strong in the long haul, particularly for hip and knee substitution applications. Titanium has been around for some time and most specialists are alright with it and are satisfied with its outcomes. Other applications for titanium look set to expand in the period to 2028. In the consumer and medical sector, the use of titanium in orthopaedic components is forecast to grow by around 3.5%.

Aircraft Requirement:

- Space applications uses around 60% of titanium manufactured product, of which over 75% is in domestic aeroplane and engines (for passenger and cargo planes).
- Over recent years the amount of titanium per aircraft has been generally increasing along with the use of composites. While older commercial aircraft, used on an average 25,000 to 30,000 pounds of titanium per aircraft, some newer aircraft use the maximum amount of 150,000 to 200,000 pounds of titanium per plane.
- Business aviation is by a long shot the biggest titanium end-use market, representing roughly 45% of complete utilization.
- Opportunities: - business airplane, military airplane, helicopter, general flying, and domestic airplane.
- Increasing Number of Aircraft: - Titanium in the worldwide avionic business is required to come to an expected $5.4 billion by 2030 with a CAGR of 3.6% from 2018 to 2030. The significant development drivers for this market are expanding conveyances of aircraft and accordingly the demand for lightweight titanium materials.
- Increasing Application: - Emerging patterns, which straightforwardly affect the elements for titanium in the worldwide aeronautic trade, incorporates creating innovation

to lessen creation cost and expanding uses of titanium in an airplane.

- For the worldwide business Jet engine build forecast, the consolidated future, and inheritance engine are required to reach more than 5,000 units in 2030, contrasted and an expected 3,500 engine in 2018. Cutting-edge engines are going to be wont to power the A320 Neo, the 737 Max, the A330 Neo, and hence the 777X. They noticed that cutting-edge engines will have up to multiple times more titanium contrasted and inheritance engines [3].

The Lockheed A-12 and its improved the SR-71 Blackbird were two of the main airplane outlines where titanium was utilized, making ready for a lot more extensive use in current military and business airplane. An expected 59 metric tons (130,000 pounds) are utilized in the Boeing 777, 45 within the Boeing 747, 18 within the Boeing 737, 32 within the Airbus A340, 18 in the Airbus A330, and 12 within the Airbus A320. The Airbus A380 may utilize 77 metric tons, incorporating around 11 tons in the engines. In air motor applications, titanium is utilized for rotors, blower cutting edges, water-powered framework segments, and nacelles. Early use in the fly engine was for the Orenda Iroquois in the 1950s [4].

Table 2.1 Requirement of Titanium for Aircrafts

Name	Titanium composite	Name	Titanium composite
Boeing 777	58 tons	Airbus A320	12 tons
Boeing 747	tons 43	Airbus A330	17 tons
Boeing 737	18 tons	Airbus A340	24 tons
		Airbus A380	77 tons

Boeing: - Boeing 787 Dreamliner is assessed to utilize 15% titanium by weight, 5% more than steel. Chicago-based Boeing Co. expects that interest in the business market is required to dramatically increase during the following twenty years. To fulfil this need, we gauge the number of stream planes will almost be two-fold to 48,000, at a normal yearly development pace of 3.5 percent, Boeing wrote in its estimate articulation. In that capacity, Boeing sees a requirement for in excess of 42,700 new commercial jet conveyances for the worldwide market, esteemed at more than $6 trillion, for development and substitution in the following 20 years. The 787 program remains the single largest individual factor in determining the outlook for domestic titanium shipments. The program's delay of more than two years has been fingered as the chief culprit for a supply chain inventory bulge variously estimated at 30 million to 50 million pounds. At 225,000 to 250,000 pounds of titanium buy weight per plane, the 787's success is seen as critical to the market's recovery [5, 6].

Airbus:- Comparative projection, Airbus, settled in Toulouse, France, expects the world armada of the business airplanes will arrive at almost 48,000 planes during the following 20 years, which remembers development for new planes at 26,540 planes, and 10,850 planes to supplant existing, maturing airplane. Everything considered, Airbus, in its worldwide market gauge report (2018-2037), expects that 37,400 airplanes will be needed during the following 20 years, addressing an expected worth of $5.8 trillion [5, 6]. the table 2.1 shows the yearly requirement of the titanium composition for the different aircraft

Regional Market Analysis

Asia-Pacific: - Represented the biggest portion of the overall industry in 2017 because of the presence of an enormous number of businesses in developing countries, like India, China, and ASEAN nations. Medical care is the quickest developing end-use industry in the district attributable to the expansion in innovative advances for the use of titanium alloys in gear that offers predominant properties, for example, imperviousness to fire, hostile to corrosion, and fatigue strength. Asia Pacific is projected to be the quickest developing provincial market, advancing at a CAGR of 4.5% as far as income over the figure time frame. Japan is the most noticeable airplane part producing centre point in the locale inferable from the simplicity of accessibility of crude materials and talented workforce. Besides, expanding R&D ventures by organizations in investigating better than ever materials are ready to drive the local market.

North America: - North America is a conspicuous market for titanium alloy inferable from the expanding request in the assembling businesses. For instance, consistent with the govt of Canada, the aviation item and parts producing parts generate a net income of USD ٢,٣ billion in ٢٠١٦ and is predicted to fill generously in the coming years. This is relied upon to fuel the demand in titanium composites [7].

North America was at the cutting edge of the field, ordering the greater part of the all-out volume in 2017. The strong presence of a raft of airplanes. Producers are one of the essential development energizers of the local market. Besides, the locale has numerous part makers. Providing parts to the aviation and defence industry, consequently advancing development.

Europe: - The European market for titanium composites is required to develop because of the rising interest from producers of common and military airplane, helicopters, drones, air motors, and different frameworks and hardware, which is probably going to move the market development. Europe experienced moderate development against the financial lull and vulnerabilities in nations like U.K. also, Italy. Besides, rising security threats in Europe are assessed to fuel the interest in a military airplane over the conjecture time frame, prompting an expansion in the demand for the item.

Latin America: - The Latin American market is required to develop at a huge rate during the review time frame, because of financial recuperation in the district which is probably going to positively affect modern growth within the region explicitly in Brazil and Mexico. The market in the Middle East and Africa is probably going to display extensive development in the coming a very long time with the expanding utilizations of titanium alloy in the oil and gas industry as titanium have high strength, against corrosion which is the need for the most difficult oil and gas applications and conditions like exploration, extraction, and filtration.

Russia: - The absolute interest of the Russian market for titanium items is described by a controlled development as per the gauges of airplane makers, and stable interest for titanium items from the mechanical area, which improvement is represented predominantly by the state projects [7, 8].

World Titanium Industry Supply Trend

Table 2.2 Titanium Market and its share in Defense & aerospace industry.

	% of Titanium	Total Titanium Quantity Production (Metric Tons)
Total		228300
A&D Industry	80%	182640
Commercial Aerospace	75%	136980
Defence Aerospace	25%	45660

Figure 2.1 Titanium Application and Market share

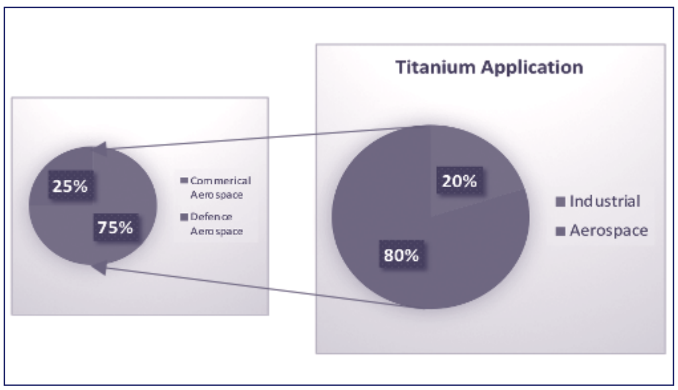


Figure 2.2 Titanium Production and Capacity

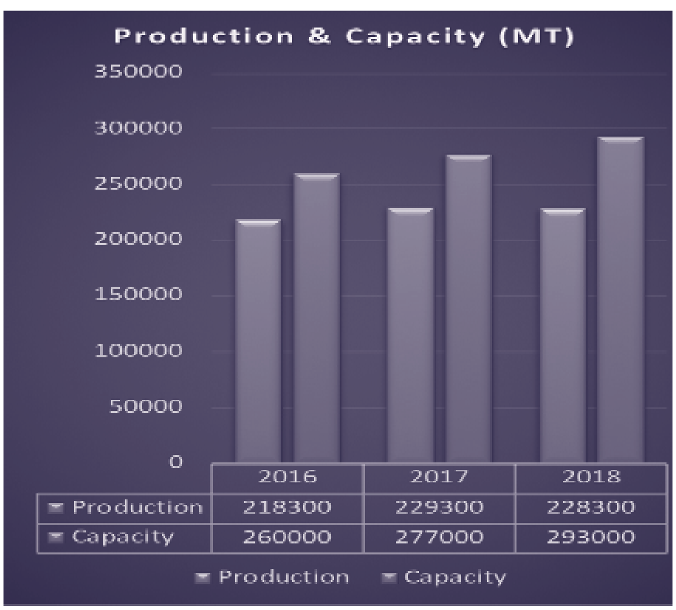


Figure 2.3 Titanium Production in MT (country wise)

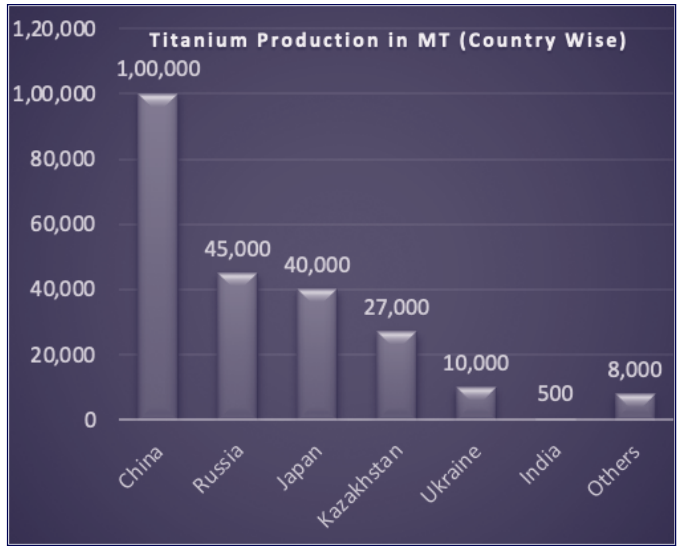
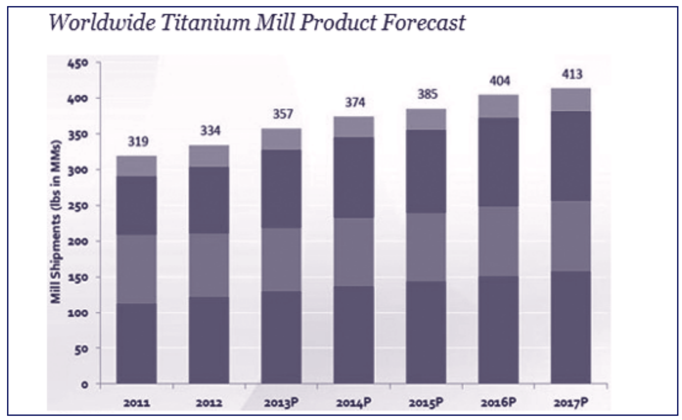


Figure 2.4 World Titanium Mill Product Forecast



Top Producers

1. ALCOA-RTI
2. ATI- Allegheny Technologies
3. Baoji Titanium Industry
4. TIMET
5. VSMPO-AVISMA

Figure 2.5 Mill Wise Total Production Capacity

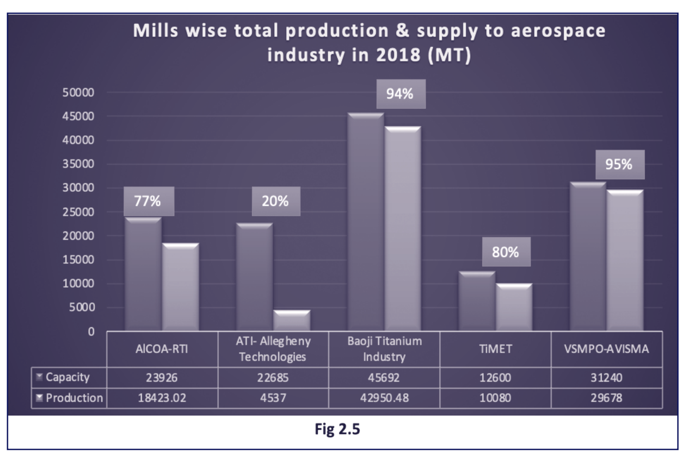


Figure 2.6 Market Share in Aerospace Industry

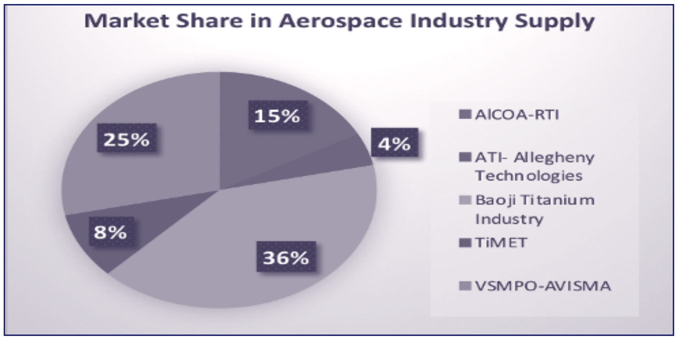


Figure 2.7 Market Share in Titanium Industry

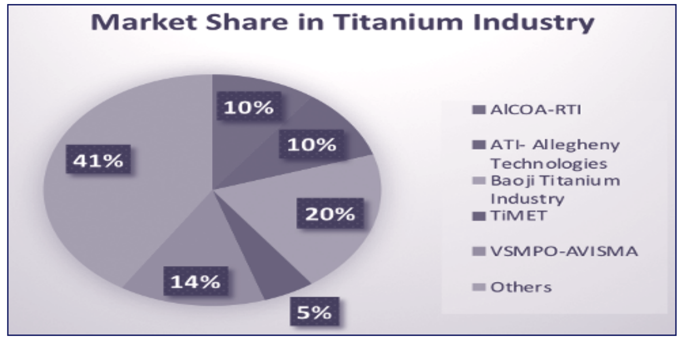


Table 2.3 Comparison and Summary of Producers [9], [10], [11], [12], [13], [14].

	Total Production in Year 2018 (MT)	% in Aerospace Industry	Total Supply to aerospace (MT)	Selling Price ($/Kg)	Total Market Share	Market Share in Aerospace Industry	Profit Margin	Revenue margin by distributor
AlCOA-RTI	23926	77%	18423.02	4.17	10%	15%	13%	13%
ATI- Allegheny Technologies	22685	20%	4537	4.18	10%	4%	6%	13%
Baoji Titanium Industry	45692	94%	42950.48		20%	36%		
TIMET	12600	80%	10080		5%	8%		
VSMPO-AVISMA	31240	95%	29678	4.03	14%	25%	25%	16%
Total	138000		105669		59%	88%		

India: Titanium Usage Scenario

Major Import from:

a. USA
b. UK
c. Singapore
d. France

The Indian space research organization with The Kerala Minerals and Metals Limited has built up a 500 tons/ year titanium sponge plant in Kollam. Subject to fulfil the annual requirement of 2,000 Ton.

Titanium Alloy is exported to 23 countries from India. The total value of export of Titanium Alloy from India is 0.85 US$ million and the leading importing nations are Nepal, Bhutan, China, USA and Malaysia [15].

Figure 2.8 Sector Wise Titanium Usage in India

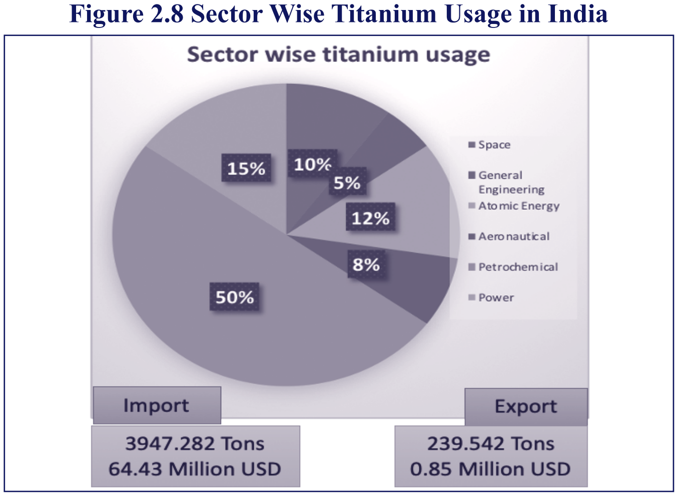


Table 2.4 Titanium Market in India

Titanium Market in India	
Defence Ministry Requirement (Tonn/ Annum)	1500
Total Capacity- KMML Plant Capacity (MT)	500
Total Production- KMML Plant Production (MT)	350
Requirement for Space program (MT/ Annum)	250

3. STRATEGIC SAFETY STOCK.

In reaction to tight material market economic situations and furthermore the appearance of uncommon however problematic occasions, the aviation and protection industry began buying an essential stock of required titanium combination crude materials. This stock should oblige huge however generally uncommon problematic occasions incorporating occasions drop in demand by customers complication in manufacturing the product leads to wastage/ producing scrap, and some organizational problem like inaccurate planning; demand forecasting; and some strategic, tactical and natural risk involved in procuring raw materials. The essential stock isn't intended to oblige moderately little variances in the material demand. Little interruptions including typical changeability inside the assembling measures are regularly obliged through stock held at upstream projecting and producing tasks or through forte metal wholesalers. Notice that this material isn't centred on material price variances. The possibly genuine purpose is to allow admittance to the material when else it'd not be free in an extremely appropriate time span. The essential security stock buffer was made in participation with industry staple providers. The metal provider is maybe the best profit with this stock. In the past, they were regularly called upon to give materials to oblige problematic occasions that were out of their control. The new essential material cushion stock took a genuine wellspring of fluctuation out of their interest prerequisites. The underlying size and design were upheld the apparent prerequisites of the business also in light of the activities and capacities of the metal makers.

Raw material safety stock category

Eight major category of the titanium alloy used in the concerned industry, and these are differentiated by the three factors **1. Type of** ***alloy {a***. *Ti 6Al - 4V (Grade 5),* ***b.*** *Ti 3Mo 2.5Ni (Grade 12),* ***c.*** *Ti 5Al-2.5Sn (Grade 6),* ***d.*** *TIMETAL 6-4,* ***e.*** *Titanium 6-2-4-2,* ***f.*** *Ti 6-2-4-6 (Ti 6Al 2Sn 4Zr 6Mo)*, ***g.***, *Ti8-1-1 (Ti-8Al-1Mo-1V),* ***h.*** *Ti 6AL-4V ELI (Grade 23)}*

2. Final form *{**a**. Billets, **b.** slabs}*

3. Location *{**a.** US, **b.** Europe}*

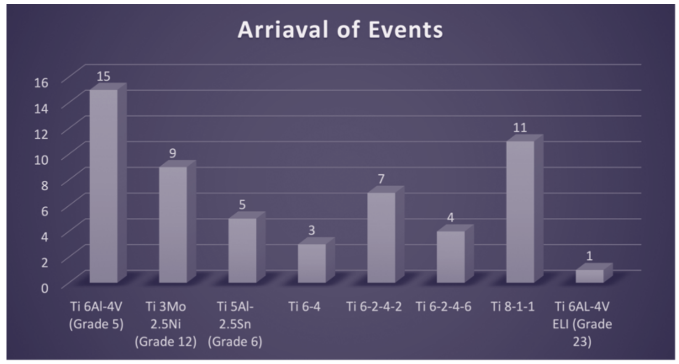
Safety stock status differentiated according to type of alloy, final form, & location where **B-** stands for billet and **S** stands for slab.

Table 3.1 Current Safety Stock

US Safety Stock	Current Status
Ti 6Al - 4V (Grade 5) **B**	4
Titanium 6-2-4-2 **B**	2
Ti 6-2-4-6 (Ti 6Al 2Sn 4Zr 6Mo) **S**	3
Ti 8-1-1 (Ti-8Al-1Mo-1V) **B**	3
Ti 6AL-4V ELI (Grade 23) **B**	2
Europe Safety Stock	**Current Status**
Ti 3Mo 2.5Ni (Grade 12) **S**	2
Ti 5Al-2.5Sn (Grade 6) **S**	2
Timetal 6-4 **B**	7
Total	**25 tons**

Modeling of the event arrival using Poisson distribution. The safety stock of strategic raw material is simply proposed to oblige the appearance of uncommon however problematic occasions in the supply chain network. It isn't expected to be utilized for ordinary and more modest interest variety. The appearance of these problematic occasions are two uncommon & stochastic & isn't best displayed by using traditional Gaussian appropriation. The following is the graphical representation of the arrival of the events for the strategic safety stock for the period of 10 years of historical data.

Figure 3.2 Expected Arrival of Events for Safety Stock



To show the impact of these troublesome occasion, their arrival of event is calculated using Poisson distribution, which specifies that the time is exponentially distributed between the arrivals of events. Comparison of the last documented observed data of 10 years to the expected result of the Poisson process is shown in ***table 3.2***. For all category the expected arrival of event is given by a Poisson Process shown by an arrival rate of ƛ **(**lambda) duplicates the observed arrival rate as determined through the examination of documented records.

The Poisson Process are used for the counting of the disruptive events.

A process

{N (t), t **>= 0}** should attain the 3 main criteria to apply the Poisson process.

Arrival rate:

i N(O)=0

ii The process has independent increments

iii The number of events in any interval of length t is Poisson distributed with mean k*t. That is, for all s, t>=O:

P {N (t + s) - N(s) = n} = $e^{-\lambda t}$ **x (ƛ*t)** ^{n} **/ n!) ….. [16].**

The principal standard basically expresses that the tallying of the arrivals begins at t=O, which is unquestionably evident in the examination of the appearance of problematic occasions in the business crude material inventory network. The subsequent basis can be straightforwardly checked by looking at our process. The arrival of a troublesome occasion prompting a material deficiency is a discrete occasion and there exists an appearance time-stretch it to such an extent that only one appearance can happen. Besides, the appearance of an occasion is autonomous of the time the last appearance happened. The third basis can be checked by analysing historical information data. Through cautious assessment of account records, stock reports, and past correspondences among industry and its crude material partner providers; a background marked by the appearance of troublesome occasions influencing the essential crude material wellbeing stock in the production network was made. ***Figure 3.1*** show pictorial portrayals of the appearance of solicitations for the distinctive key crude material safety stock [16,17].

Table 3.2 Observed and Expected Arrival of Event

Ti 6al - 4V (Grade 5) US Event Arrival For Billet			
Events	**Detected**	**Observed %**	**Expected (λ = 0.0296)**
0	506	97.03557312	97.08
>=1	15	2.964426877	2.92
Titanium 6-2-4-2 US Event Arrival For Billet			
Events	**Detected**	**Observed %**	**Expected (λ = 0.0211)**
0	425	97.88235294	97.91
>=1	9	2.117647059	2.09
Ti 6-2-4-6 (Ti 6al 2sn 4zr 6mo) US Event Arrival For Slabs			
Events	**Detected**	**Observed %**	**Expected (λ = 0.0135)**
0	370	98.64864865	98.65
>=1	5	1.351351351	1.35
Ti 8-1-1 (Ti-8al-1mo-1v) US Event Arrival For Billet			
Events	**Detected**	**Observed %**	**Expected (λ = 0.0078)**
0	381	99.21259843	99.22
>=1	3	0.787401575	0.78
Ti 6AL-4V ELI (Grade 23) US Event Arrival For Billet			
Events	**Detected**	**Observed %**	**Poisson Expected (λ = 0.0171)**
0	408	98.28431373	98.3
>=1	7	1.715686275	1.7
Ti 3mo 2.5ni (Grade 12) Europe Event Arrival For Slabs			
Events	**Detected**	**Observed %**	**Expected (λ = 0.0109)**
0	365	98.90410959	98.91
>=1	4	1.095890411	1.09
Ti 5al-2.5sn (Grade 6) Europe Event Arrival For Slabs			
Events	**Detected**	**Observed %**	**Expected (λ = 0.0320)**
0	343	96.79300292	96.85
>=1	11	3.206997085	3.15
Timetal 6-4 Europe Event Arrival For Billet			
Events	**Detected**	**Observed %**	**Expected (λ = 0.0039)**
0	256	99.609375	99.61
>=1	1	0.390625	0.39

Chi-square Goodness-of-Fit Test

The chi-square goodness-of-fit test is utilized to test if an example of information came from a populace with a particular distribution [13]. In the above instance of demonstrating the appearance of troublesome occasions requiring material from the essential crude material stock, the chi-square goodness of fit test gives a helpful instrument to testing the noticed information to the normal yield of a Poisson process as shown in fig 2.2. The chi-square goodness-of-fit test is applied to data that has been binned or set into classes. This is useful for a discrete circulation like the Poisson scattering [17]. One of the main contemplations while utilising the chi-square goodness of fit test is the requirement of adequate information. For best outcomes there ought to be at least 3 bins or characterisations each with at least five data points.

In order to achieve the minimum of five data points in three different bins, the data is segregated in the below category

Bin1**:** zero event arrivals in month
Bin2: 1 event arrival in month
Bin3: >=2 event arrivals in month

The null hypothesis for this test is that the observed data follows a Poisson process. The alternative is that the data does not follow a Poisson process.

H0: Data follows Poisson process.

HA: Data does not follow Poisson Process.

Test Statistic: $\chi 2 = \sum ki{=}1(Oi - Ei)/Ei$ .....[17].

a.Where Oi the data is observed and Ei is the expected outcome from a Poisson Process.

If $\chi 2 >= \chi 2\ \alpha$ k-1 Reject Ho

If $\chi 2 <= \chi 2\ \alpha$ k-1-m do not reject Ho

$\chi 2$ Degree of freedom = K -1 → 3 - 1 = 2

$\chi 2$ Degree of freedom = K - 1- M →3 – 1 - 1 = 1

Where;

K is the number of classes

M is the number of estimated parameters

Level significance $\alpha = 0.05$

a. $\chi 2$ 0.05,2 = 5.992

$\chi 2$ 0.05,1 = 3.843 (from table)

Poisson λ =[(88*0) + (25*1) + (4*2) + (3*2) + (1*4)] /120 = **0.438775**

Table 3.3 Conclusion for the arrival of the disruptive events:

Events	Expected probability	Expected Number	Observed Number	O-E	$(O-E)^2$ / E
0	64.48%	84.5	88	3.5	0.144970414
1	28.29%	28.98	25	-3.98	0.546597654
2	5.20%	5.44	4	-1.44	0.381176471
3	0.97%	1.08	2	0.92	0.783703704
4	0.09%	0.11	1	0.89	7.200909091
5	0.008	0.01	0	-0.01	0.01
>= 2	6.27%	6.64	7	0.36	0.019518072
Chi Square					**0.71108614**

In ***table 3.3*** we calculated the chi square using the above formula the calculated value is 0.711 < 3.843 there is no proof to say that the data do not follows a Poisson distribution.

Generally speaking, the chi-square goodness of fit test affirms what can be instinctively derived from ***table 3.2*** namely that the Poisson process does a brilliant job of repeating the appearance of troublesome occasions for the essential crude material stock [17].

4. OPTIMIZATION OF THE STRATEGIC SAFETY STOCK

What's optimal amount of safety stock that we must keep in our organisation. So that the probability of stock-out is as per desired service level a pre-requisite for this then is an establishment of a service level. A service level is a policy measure set by supply chain managers, to help them determine the level of safety stock that needs to be kept to protect themselves from stock-out situations. It's basically a strategic decision taken by the top organisation to decide the serviceability of the demand. Two types of service levels commonly used in inventory control are:

1. A measure based on the proportion of order cycle in which no stock outs occur.

2. A measure based on the proportion of customer requirement that is satisfied from the on-hand inventory, also referred to as the fill rate.

There are several methods for determining the safety stock.

But each one of them requires a thorough analysis of

A. historical lead time and

B. demand data.

By using the enterprise resource planning system there are various ways through which we can obtain data related to an average lead time of the particular material and the average demand for the specific period. The demand data can also be obtained from consumption master files. Because in any organisation whenever there is an issue that issue transaction is being captured in the database [18]. And over a period of time, we can extract all those issue transactions to find out average demand and the standard deviation of demand for any particular item. Similarly, this historical lead time though we can have defined that lead time is the difference in time between the placement of purchase order and receipt of the item. This receipt of the item can be obtained from the computer systems based on the receipt of the goods date. And we know the purchase order date, so we will get the difference between dates to get an idea or measure of lead time and we will capture all the receipt transactions over a period of time to get the average lead time and the standard deviation of lead time. When adequate data is available, we can fit statistical distribution to describe demand during lead time. And normally we assumed normal distribution to fit as the distribution of demand during lead time.

Although any other continuous distributions may be used. When considering safety stock, we have to keep in mind the following three situations.

That may normally be encountered while determining the safety stock.

1. Variable demand, constant lead time

2. Constant demand, variable lead time

3. Variable demand, variable lead times

In case of the aerospace and defence industry the demand is well known in advanced as the assembling of the new aircraft is a well-planned process. Generally, the request is known well ahead of time. As a subsidiary of plane deals, creation plans are regularly set a year ahead of time. Therefore this industry falls in 2nd situation i.e. constant demand and variable lead time. As we discuss in the previous part in the Titanium market scenario there we observe that because of the few producers of the titanium alloy and in India we cannot fulfil our own requirement (i.e. government sector requirement) the private companies are fully dependent on the imports. When the imports are comes in picture the lead time for the various alloys of [19].

The titanium is different as they have to import from different locations. Also, we have to consider the risk factor which leads to the variable lead time [14, 15].

In this case the reorder level is given by

R = d $\bar{L}$ + Z * d * σl ...... [20]

Where:

d = daily demand

$\bar{L}$ = Average lead time

Z = standardized normal variate (depend on service level)

σl = standard deviation of lead time

Table 3.4 Inventory Optimised at 95%

Inventory category	Current Inventory	Optimized for 95 % service level
T_i 6Al - 4V (Grade 5) **B**	4	6
Titanium 6-2-4-2 **B**	2	3
T_i 6-2-4-6 (T_i 6Al 2Sn 4Zr 6Mo) **S**	3	3
T_i 8-1-1 (Ti-8Al-1Mo-1V) **B**	3	2
T_i 6AL-4V ELI (Grade 23) **B**	2	2
T_i 3Mo 2.5Ni (Grade 12) **S**	2	2
T_i 5Al-2.5Sn (Grade 6) **S**	2	2
Timetal 6-4 **B**	7	3
Total	**25**	**23**

Stock choices are frequently made by looking at the expense of holding stock when contrasted with the expense of a stock out also by referring to the historical data for the demand. This computation has been deliberately avoided with regard to this paper because of privacy concerns. All things considered, as an essential stock intended to cover uncommon yet problematic occasions, an administration commanded a level of service is 95% was utilized. Under this thought, one can see that **(in table 3.4)** the current stock levels are adequate much of the time except for T_i 6Al - 4V (Grade 5) billet inventory, and Titanium 6-2-4-2 billet inventory. Additionally, in the case of T_i 8-1-1 (Ti-8Al-1Mo-1V) Billet and Timetal 6-4 billet a reduced inventory could still meet the 95% service level.

5. DISCUSSION

Titanium has various exceptional attributes that make it a fundamental contribution to the assembling of combustion turbine motors. Its high strength-to-weight proportion, erosion obstruction, and protection from high temperatures make resistance like properties makes it a very important metal for the aerospace and defence industry or any industry where the strength to weight ratio deciding factor. The titanium metals industry is an oligopoly with huge obstructions to the passage as it requires huge capital and expertise to build a plant. It is generally determined by the aeronautic and defence trade and is dependent upon serious cyclicality. This cyclicality puts an uttermost pressure on industry firms during times of reduced requirement and has brought about a mindful limit extension during times of increased requirement. The Industry upholds a strategic safety stock of titanium alloy raw materials. The fundamental question asked to an author at the time of the initial stage was in case of the tight supply chain market of the titanium would you be able to disclose to us how all around canvassed the business is concerning our essential titanium stock?

To foster experiences, a complete audit of titanium stock and accounts data was directed and a history of disruptive occasions requiring titanium was made. These generally uncommon however problematic occasions were found to show up as per a Poisson Process. In Poisson process the we understand the arrival of events follows the regular interval or the exponential intervals for the metal Ti 6Al 4V the observed frequency where 0 event is occurred is 97.03% and for >=1 event the observed frequency is 2.96% and the Poisson expectation for the same meta is 0 event 97.08% and for >=1 evet is 2.92% which is almost replicating the observed data similarly for the other metals we found that the replication of observed in Poisson expected. Using the enterprise resource planning system there are various ways through which we can obtain data related to an average lead time of the particular material and the average demand for the specific period. Furthermore, the data is validated using the chi-square goodness of fit test affirms what can be naturally found from ***table 3.3*** Namely that the Poisson process does an excellent job in imitating the appearance of problematic occasions for the essential crude material stock. As the calculated value of chi square (i.e. 0.711 < 3.843) is less than the table value. Moreover, the strategic safety stock of the various titanium alloy is calculated by determining the service level, demand and the average lead time for the different material the full result can be found in ***table 3.4.*** The table shows that the to achieve the 95% of the service level for the most of the material the safety stock is remains same (Ti 6-2-4-6, Ti 6Al-4V Eli, Ti 3Mo 2.5Sn) the current inventory can fulfil the required 95% service level. Whereas for the material Ti 6Al - 4V (Grade 5) billet inventory, and Titanium 6-2-4-2 billet inventory the current safety stock cannot accommodate the 95% service level therefore the 2 nits and 1 units of respective material is additionally required.

Similarly in case of metal Ti 8-1-1 (Ti-8Al-1Mo-1V) Billet and Timetal 6-4 billet the company is carrying the extra inventory which need to be reduced by 1 unit and 4 units respectively, by reducing still be can achieve a serviceability of 95%.

6. CONCLUSION

The price of Titanium is going to increase in the coming future, owing to fluctuation in demand and price-sensitive approach from suppliers related to production, which may result in constant to little increase supply of Titanium, therefore, holding a strategic raw material in optimum quantity is essential.

i. We studied the pattern of arrival of events that's exponential and validated using the chi square where we find the value of calculated is less than the obtained (0.711< 3.843) in ***table 3.3*** which confirms the data is exponentially distributed.

ii. As the demand is well known and the lead time is variable because of tight titanium market we used the constant demand and variable lead time model to calculate the safety stock at 95% service level and shown in ***table 3.4*** likewise the company can calculate the safety stock at different service levels like 96% up to 99.5% which is uncommon in industry as the service level goes on increasing the raw material safety stock is moderately increases. Therefore the company sets the serviceability at 95% which is commonly used in industry standards.

iii. With companies actively looking to work down inventory levels we had to study the pattern of the arrival of the events for the particular material to suggest the holding of that material by considering its lead time, demand and the serviceability.

iv. The future supply-demand balance remains somewhat uncertain at this time, with industry observers sensing early signs of a moderate tightening of supply, while others predict domestic lead times could come in a little further. It appears that much depends upon how quickly inventories are worked down and when industrial markets particularly the aerospace sector and defense sector —begin to recover.

Lastly, the aerospace and defense sector will be driven by smart companies. As the companies are implementing a more and more advanced system like industry 4.0, Artificial intelligence and machine learning, cloud computing, big data, additive manufacturing etc.; these technologies are enabling companies to gather, read and analyze the real-time data of each activity. That information ensures an uninterrupted supply chain for the critical parts in real-time and with minimum wastage. The relation between the original equipment manufacturer (OEM) and their supplier would go beyond buyer and seller relationship to "being the part of the business", giving rise to a new range of risk and revenue sharing business model.

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