INVENTORY MANAGEMENT BEST PRACTICES FOR AIRCRAFT SERVICING INDUSTRY IN INDIA

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Inventory Management is one of the key areas within an Aircraft Servicing and Maintenance organization. The management of aircraft spares, Line Replacement Units (LRUs), Rotables, special hardware items and consumables of an aircraft or aircraft servicing, maintenance, repair and overhaul (MRO) facility includes several key areas starting from demand management, modelling and forecasting, material management, order fulfilment and tracking of movements, warehouse management and physical inventory control.

In a traditional hierarchical inventory system, direct orders are the only information for inventory management that is exchanged between the firms in the Supply Chain. But due to the rapid development of modern information technology, it becomes possible for the firms to share more information in real time, e.g., demand and inventory status data along with inventory information with integrated Supply Chain links. As such Indian Aircraft Industry (IAI) aimed at such information sharing with the supply chain because IAI has recognised this as an important source of competitive advantage.

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In order to achieve objective of optimizing the inventory holding level at Indian Aircraft Industries, especially at the aircraft servicing centers, various Selective Inventory Control models have been used during the past fifteen years which have yielded results to bring down the level of inventory to its minimum, have been elaborated upon in this paper.

Selective control is based on the principle "Take maximum care of the most important thing". This is the prudent approach of any management. Similarly in inventory management classification of inventory and grouping of inventory is resorted-to, so that major portion of managerial time is spent effectively on materials which are important. There are many methods for this selective control. The methods followed in Indian Aircraft Industries are reviewed in this paper with suggestions for improvement apart from utilization of Inventory Modelling and neural networking methods.

Keywords: Selective Inventory Control Techniques, Neural Networking, Indian Aircraft Industries – Aircraft Maintenance & Servicing Systems Software, (IAI-AMSSS), Clean Exchange, Calendar plan & Order Risk Policy.

Inventory Management Scenario

Excessive costs of holding inventory have been a constant problem and challenge for Aircraft Servicing Industries. Systems are now available that allow these industries to make reductions in inventory through systematic and scientific analysis along with close monitoring with Customers. An aircraft servicing industry must also carefully control many regulatory aspects, including technical records of parts, quality control and hazardous material control.

Inventory management is linked with many aspects of engineering and maintenance operations, so it cannot be viewed in isolation. IAI with its integrated practices avoided the mistake of 'data silos' by the use of separate Information Technology systems for materials from the rest of the Maintenance Repair and Overhaul (MRO) environment while maintaining best inventory levels.

Some of the Aircraft Industries are holding more than Rs. 16 Crores ($2.5 million) of inventory per aircraft. They hold a lot of stock, but most seems to be the wrong part numbers or to be in the wrong place, since the airlines suffer from part shortages, which cause delays. This is a classic problem of an aircraft industry, with either an old MRO system, or a collection of disconnected systems and 'home-made spread-sheets' providing little or no management information to help drive inventory down.

Parts provisioning

A cornerstone of good material management is planning and forecasting. Spares provisioning is an extremely complex process because 80-90% of it is sporadic, and so difficult to manage. The intertwined relationship between these parameters and the exponential relationship between holding quantities and fill rates, or the percentage of time that a required part is immediately available, results in a problem with many variables.

Without sophisticated dedicated tools, the spare parts planner faces the impossible task of provisioning for spares in this complex environment, resulting in poor fill rates due to shortages, poor aircraft despatch rates and extended **A**ircraft-**O**n **G**round (AOG) situation.

This normally uses inputs of previous failure rates and projected future aircraft utilisation rates. Obviously the third big factor is stocking policy. In other words, the crucial issue is how much of a safety buffer to be built-in to cope with peaks or spikes in demand. One critical concept that IT systems need to cope with is multiple part numbers within an interchangeable family, and across multiple stock locations in an enterprise, including both owned stock and non-owned consignment stock.

The main benefit for an airline or an MRO facility is to provide a high fill-rate for spares demand with the minimum amount of stock. A system should be developed in such a way that it can assist spare parts planners to better assess re-stocking policy by looking at seasonal re-ordering. The system need to look at contractual constraints or opportunities to reduce cost. Integration of stocking policy into the procurement module is critical to offering this capability.

Spares Forecasting

What options does an airline with an old legacy MRO system have if it wants to improve inventory management without replacing its entire core MRO software system? There are vendors with point solutions for the problem. These are systems that purely address the issue of provisioning and forecasting, and can be integrated into old systems. There is a balance between volume of stock and the costs incurred by lacking inventory when required. The goal is to find the optimum cost point for an operation.

Configuration of IPC & SOP

Part master data, ‘Standard of Preparation’ (SOP) and the Illustrated Parts Catalogue (IPC) in particular, need to be managed to maximise the benefits of modern Information Technology systems. This is the second big lever with which Information Technology systems and neural networking systems can help to manage inventories and to achieve management control. But how easy is it to keep the data up to date? “No one wants to update the entire IPC database every time the original equipment manufacturers (OEMs) issue revisions,” says Mr. Sanjay Awasti at IAI. “But IAI has a data import tool in their system”. “IAI can upload the IPC into Customers systems, but the reality is that a mechanic is obliged to view parts in the OEM’s IPC any way. IAI can make the IPC available in the system via a link LAN-WAN, using specific software or even the OEM's own software. But adding new part data in the systems database is done manually by the engineering department.

It is their job to assess what part supersedes another, what the inter-changeability rules are, and then set up the part master data in the system. It is not an automatic process. It is quite normal for new parts not to be re-loaded into the system if they are alternative and interchangeable. The Aircraft Servicing Industry takes the unknown part number and adds all its engineering and purchasing data into the system once it has been ordered by a mechanic. While this takes time, it is more efficient than loading every conceivable part into the system, just in case someone orders the part later.

Logistics –IAI AMSSS

If an airline can move stock more rapidly, it will achieve three benefits: lower overhead costs; lower work in progress (WIP); and so, ultimately, less inventory. High inventory does not always result in higher operational reliability. However, the right parts need to be moved to the right place at the right time. There are several elements to good logistics management, starting with the receiving process at a location, but also including the visibility of a part's physical position. "Receiving varies widely between airlines around the world," comments Mr. S K Chopra, General Manager (IMM). Somebody receives, inspects and certifies the part for release. IAI has got three stages to the process: one department receives and unpacks parts; a second inspects paperwork, looks for damage and deals with any discrepancies; and a final group performs airworthiness inspections and release. "Systems need to be adaptable to each situation," continues Mr. Chopra. "***Indian Aircraft Industries – Aircraft Maintenance & Servicing Systems Software*** (IAI-AMSSS) can provide visibility for all stages, and parts move electronically through each process. IAI-AMS wing is now planning for single step receiving. Qualified inspectors receive items, complete checks for service bulletin and modification status, check serial numbers, and enter batch numbers. They also complete customs data entry. This would facilitate system improvements apart from accountability by the professional inspectors.

In IAI, Bar-coding is used at all stages to make the process efficient. While bar-coding and mobile handheld devices are widely used in the material area, radio-frequency identification tags

(RFID) are also used at IAI Servicing, Maintenance and Repair Centres. IAI-AMSSS also allows the user to identify parts that are required for AOG situations in particular shipments, and to track the shipment on-line via the shipper's web portal. Goods receiving and shipping management can shave a day or more from the '**T**urn **A**round **T**ime' (TAT) of an item. This can be worth 2-3% of the total material budget, presenting another cost-saving opportunity. The management of part movements through a dispersed airline enterprise, after receiving, is complex.

Deciding which parts to place where, and when, can affect stocking levels by as much as 10%. IAI-AMSSS tracks part locations and movement history is simple. At IAI now systems can track the internet protocol (IP) address of the computer that did a booking into a particular location, since IAI-AMSSS uses a web-based application.

Warehousing Challenges

The biggest challenge for a material department is the warehouse. While many warehouses in IAI have sophisticated automated picking and stowage, and active RFID tags with handheld technology, this reality still seems a long way off for many Indian Industries in Aircraft Servicing as well as airline companies. There remain many aviation warehouses that lack bar-coded warehouse bins, and use handwritten labels for stock. IAI has got very sophisticated stores, where the bin information itself, indicates bin size and weight limits along with component shelf life as applicable and also alternate part numbers and next assembly numbers.

An airline warehouse deals with inward and outward parts, unserviceable parts, and legal requirements for control of handling, managing internal routing, and external routing of parts and hence the Inventory management is highly complicated. Issuing of parts is also to be systematic and the parts tracing in the aircraft industry play a predominant role. When a demand for a part is received, picking would normally be done on a first-in-first-out (FIFO) basis. But this may not be appropriate for an airline, depending on the shelf life and condition of the item, such as whether it is repaired or overhauled. It is great for the OEMs, which can manage a manufacturing environment, but is RFID tagging worth it for an airline that deals with a range of parts, some with or without tags. There is a lack of standards, and the airline faces significant hardware investment to read and manage tags. Bar-coding is high-tech and costly for small units. Stock-taking or physical inventory management is another area where airlines can gain from modern IT systems if utilized properly.

The starting point is clean data for the receiving and issuing of parts, and plenty of computer-based validation for any transaction, so that the chance of errors in stock level data is minimised. IAI-AMSSS runs a standard 'ABC' type analysis, where it bases the analysis of stock on relative valuation: A for high, B for medium and C for low. The system can undertake a rolling stock-take of physical inventory by taking mini-stock takes of small areas of a warehouse on a regular basis. This may be appropriate for the high-value, or fast-moving items. It can do spot checks or samples of inventory for high-value parts, or parts where fill rates are dropping below target levels. The periodicity of checks can be automatically set.

IAI-AMSSS can be asked to recommend a stock-take for less than 100 components, or one that will take two hours. The system would also provide information about consumption or issues that have taken place during the stock-take. This is automatically factored into the reconciliation. "We never freeze a location while we perform a stock-take; that is very old-fashioned. The warehouse is there to serve its maintenance customers, and we never tell customers we are closed for a stock-take" as per Mr. MV Rao at IAI.

Inventory Valuation

Accurate inventory valuation is a constant challenge for an aviation maintenance organisation. Significant excess cost and time are needed to reconcile discrepancies in the valuation. IAI had a separate, central finance system that takes care of reconcile data across an interface with the maintenance department and taking care of the specific LRU's traceability with various customers. The problem is less likely with third-party (Outsourcing) maintenance companies, because they only have one business focus, and the material management processes are a central part of that business. The outsourced company is responsible for the specific units given to them for specific repair or overhaul of Avionic parts or others.

"IAI-AMSSS uses constant moving average value (CMAV) method for inventory calculations" as per Mr. Rao. "The majority of our customers use this. CMAV is where the system takes the price at which parts were purchased over a period, adds all the valuations for a part number and divides the total by the quantity of parts to produce an average price. The average is updated with the new data as more parts are purchased, hence the term 'constant moving'. Of course this does not reflect the market valuation of an item. The CMAV is used for balance sheet calculations by the finance department. Some of IAIs customers grab an extensible mark-up language (XML) file of prices and part numbers from online IFS/ ERP, and run this against the inventory held in IAI-AMSSS for market values. This can be updated regularly to get an idea of the real economic value of a part in the open market, which can sometimes be very different from the purchase price.

Standard Parts & Service Logistics

Indian Aircraft Industry provides Service Logistics and sources, stocks and delivers Standard Parts in kits for aircraft MRO team. The innovative Standard Parts Bundles consist of all the required standard parts for the specific maintenance of a specific aircraft type, which are placed in all the work locations of the aircraft technicians. The kits also include shelf-life items and consumables.

When the work is finished, Indian Aircraft Industry's retrieval team will retrieve the remaining standard parts and provide a total overview of the used parts, including the certificates. For medium and large aircraft, the Standard Parts Bundles are delivered directly to the exact work location of the aircraft technician, in all aircraft work zones. For smaller aircraft or subassembly zones, the Standard Parts Bundles are supplied in a trolley that can be placed in the direct vicinity of the aircraft. The daily support of flight operations and ad-hoc maintenance is delivered via a Kanban system.

The system of Rotables & LRU's Management

Rotables/ Line Replacement Units (LRU's) are small assemblies, subassemblies and critical spare parts which are having significant inter-changeability and used for maintenance, overhaul and repair of the aircraft. IAI, Kanpur division deals with four major types of rotables for Dornier-228 aircraft.

1. Hydraulics or mechanical rotables
2. Electrical rotables
3. Instrumental rotables
4. Avionics and Radio rotables

All rotables have certain fixed flight hours or shelf-life (whichever occurs earlier) after which they require servicing or overhaul. The rotable overhaul department carries out major task of repair/overhaul and follow-up of various types of rotables. Among all rotables of Dornier-228, a part of them where facilities are not available in this division, are sent to different repair agencies like foreign vendors (original manufacturer), IAF maintenance depot, private agencies, ECIL and sister divisions of IAI.

Removal of rotables from aircraft begins as soon as ground run and preliminary survey are over. This activity goes parallel with survey and zonal inspection routines. After removing, the rotables are given for inspection and type of repair is suggested for each item by respective inspectors.

Rotables Repair – Clean Exchange – Calendar Plan

The cycle time for 1200/2400/3600 hrs servicing of Dornier-228 Aircraft according to the present schedule followed in the shop is 26 weeks. Majority of the LRU's / Rotables are to go to foreign vendors for repair and are to come back to be fitted into Aircraft. To avoid delay a special agreement is made with the OEM's that the rotable sent to their work would get delivered to IAI with-in a calendar period of 7 days with a special contractual fixed repair price agreement based on the condition of item as decided by the Manufacturer/ repair agency at foreign works. This new method of agreement reduced the cycle time of Rotables repair considerably apart from cost savings in administrative work.

Effective Inventory Management

The inventory management has been done with proper analysis as per Aircraft and Cost requirements. Selective Scientific Inventory Control Systems, which are proven since ages are best but need to be used in combination for achieving better control of inventories and improving service level. Various measures in this line are-

a. The VED Analysis of Units
b. The ABC Analysis of Parts/ Units
c. The Replacement theory/ Clean Exchange of LRU's/ Rotables with Foreign Suppliers
d. Stock Piling of Scarce Items and Safety Stocks.
e. Design Modification of Difficult to Source items
f. Integrated Inventory database of Various Divisions of IAI
g. Inter-net Procurement/ E-procurement
h. E-Commerce
i. Use of Parts Locators and Search engines to locate the parts worldwide and source them through Internet use.
j. E-Purchasing
k. Data Labels and Automated Inventory Identification and Location System
l. Neural Networks

Table 1: Selective Inventory Control techniques used in IAI

Sl No	Selective Control Type	Criteria of Selection	Main Use & Objectives	Remarks
1	ABC Analysis	Consumption Value	Take maximum care of the most important thing	This do not take Criticality of Item into Account
2	XYZ Analysis	Stock Holding Value	To Review the Investment	This do not take Criticality of Item into Account
3	FSN Analysis	Movement of Items	To Combat Obsolescence	This do not take Criticality of Item into Account

4	VED Analysis	Criticality of Item - Vital few and Trivial Many in terms criticality.	To determine service level for the item	This does not take value of the item into consideration.
5	Combination Methods	The Combination of these methods like AX, NX, VX, VA & FA are also being used for better analysis.	Better Analysis and Management of Stocks	Since it is a combination, all issues would get considered

Selective Inventory Control

Selective control is essential part on the basic principle "Take maximum care of the most important thing". This is the prudent approach of any management. Similarly in inventory management classification of inventory and grouping of inventory is resorted-to, so that major portion of managerial time is spent effectively on materials which are important. There are many methods for this selective control. The methods followed in Indian Aircraft Industries are given in Table 1.

ABC Analysis

ABC Analysis is a basic analytical Management tool which enables the Managers to place the effort where the results will be the greatest. The basis is the peculiar phenomenon "***VITAL FEW TRIVAL MANY***" in terms of its consumption value – the Pareto's law. This technique is popularly known as 'Always Better Control' or the 'Alphabetical Approach'. The technique tries to analyze the distribution of any characteristic by 'money value' in order to determine priority.

Selective scientific control of inventory calls for categorization of inventory on the basis of consumption value. For achieving the objective of overall financial control with the development of limited resources this analysis got significant importance at IAI. In general the annual consumption analysis of an organization would indicate that a handful of top high valued items – less than 10% of the total number will account for a substantial portion of about 75% of the total consumption value, and these few crucial items are called "A" class items which need careful attention. Similarly a large number of 'bottom items' over 70% of the total number called the 'trivial many' account only for about 10% of the consumption value and are known as the "C" class items. The Items that lie between these two are called the "B" category items. The objective of carrying out ABC Analysis is to develop policy guidelines for selective control.

"A" Class items are controlled tightly in the inventory system of IAI with constant attention by both purchase and stores management. A large effort for few items can cost moderately but the effort can result in large savings. "B" items are controlled formally with periodic attention and "C" class items are controlled through a simple system designed to cause least trouble for the purchase and stores department. The detailed guidelines followed at IAI are as follows:

A_ Class Items: Very Strict Control, Low Safety stocks, Frequent deliveries, Maximum follow-up, Centralized Purchase Controls, Calendar plan indenting, Constant source development, Minimum surpluses and obsolescence, reduced lead time and individual postings. Forecasting based on Norms and Targets of Production, Stock-piling with high level approvals, staggered delivery recommendations, Purchase Orders placed for supplies over a period of time with applicable escalation formulae if any.

B_ Class Items: Moderate Control, Low Safety stocks, deliveries in once in 3 months, periodic follow-up, Limited reliable source development, Calendar plan indenting, Estimates based on at last 3 years data, reduced lead time, combined and decentralized purchasing, Moderate control on Surplus and obsolescence.

C_ Class items: Loose controls, high safety stocks, deliveries once in 6 months, Bulk ordering, few sources of reliability, annual review, group postings, decentralized and rough estimate purchasing, minimum clerical efforts.

The following value limits for A, B, B1, C categories have been fixed in IAI.

Table 2: ABC Categorization at IAI

Sl No	Category	Consumption Value Limit
1	A Category Items	Rs. 10.00 Lakhs and Above
2	B Category Items	Rs. 2 to 10 Lakhs
3	B1 Category Items	Rs 0.5 Lakhs to 2 Lakhs
4	C Class Items	Less than Rs. 0.5 Lakhs

In this analysis only those items have been considered which are having some consumption during the year. The items having 'nil' consumption during the year have not been considered in this analysis.

The comparative figures under these categories for the past 5 years have been given below. These figures clearly indicate that during the year much better control has been envisaged to have better control on A class items. The consumption of these A class items is 84.45 % with 36 (35.86) days stocks against the Industry Norm of 60 days.

The ABC Analysis report for Indian Aircraft Industry's special division at Kanpur for Specific Dornier-228 Aircraft is shown in the table below-

Table 3: ABC Analysis of the items for years 2009-10 to 2013-14

(IAI's Dornier Aircraft Servicing)

Year/ Class	A CLASS		B CLASS		B1 CLASS		C CLASS	
2009-10	327	4210	375	391	547	325	3818	155
2010-11	321	4120	265	399	544	326	4214	132
2011-12	317	4414	264	378	534	324	4219	147
2012-13	309	5634	255	478	537	416	4199	183
2013-14	308	5614	245	437	503	414	5641	180

* All items in Numbers and Value in Rupees Lakhs

Table 4: ABC Analysis in Number of Days Stock Holdings

(IAI's Dornier Aircraft Servicing)

YEARS	A CLASS	B CLASS	B1 CLASS	C CLASS
2009-10	65	474	263	585
2010-11	62	376	221	574
2011-12	52	302	321	376
2012-13	38	254	384	368
2013-14	36	302	374	301

Table 5: ABC Analysis in % of Items and Value

(IAI's Dornier Aircraft Servicing)

CATEGORY	Annual Consumption Value (%)	No of Items Consumed (%)
A Class	84.45	4.60
B Class	6.57	3.66
B1 Class	6.23	7.51
C Class	2.75	84.23

The stock holdings of "A" Class items shows down trend, which is a positive sign for the management of high consumption value items in terms of number of items. These high value items of 308 numbers (4.6 % of total items) have taken care of 84.45 % consumption value of stores and spares during the year 2013-14. But at the same time B class items shows an upward trend indicating that the loose control on this category and thereby Non Moving inventory in B, B1 and C class items are on the increase. It can also be inferred that the "A" class items were taken maximum care to avoid surplus, obsolescence and Non Moving inventory in High Value inventories.

Perceptual stock verification with RFID tags and inter-changeability recommendations of B, B1 and C class items have been proved to be helpful in reducing the heavy stocks and to reduce overall inventory. But stock piling of few of the items in B B1 and C category items in view of anticipated scarcity of particular items due to various reasons, is the cause of their inventory holdings increase.

Stock Holding Analysis (X,Y,Z Analysis)

For ensuring constant weeding out of unwanted inventory, stock holding analysis got significant importance. Wherever the stock holding is high and there is no movement, one can ensure closer monitoring of such items. The criteria for declaring an item under X,Y,Z. class shall be "on stock value consideration basis" as given in the table 8 below. The detailed analysis is given in the following tables 6&7-

Table 6: XYZ Analysis for Years 2009-10 to 2013-14 (Items & value)

(IAI's Dornier Aircraft Servicing)

Year/ Class	X CLASS		Y CLASS		Y1 CLASS		Z CLASS	
2009-10	328	5432	387	412	446	387	3243	432
2010-11	354	5436	324	414	448	423	3456	328
2011-12	321	5212	345	642	564	541	3478	322
2012-13	298	5444	355	571	551	645	4212	342
2013-14	264	3534	286	643	918	893	3690	480

Table 7: XYZ Analysis for Years 2009-10 to 2013-14 (% Items and %Value)

(IAI's Dornier Aircraft Servicing)

Class	**X CLASS**		**Y CLASS**		**Y1 CLASS**		**Z CLASS**	
Year	% Items	% value	% Items	% value	% Items	% value	% Items	% value
2009-10	7.45	81.52	8.79	6.18	10.13	5.81	73.64	6.48
2010-11	7.73	82.35	7.07	6.27	9.78	6.41	75.43	4.97
2011-12	6.82	77.59	7.33	9.56	11.98	8.05	73.87	4.79
2012-13	5.50	77.75	6.55	8.15	10.17	9.21	77.77	4.88
2013-14	**5.12**	63.68	**5.54**	11.59	**17.80**	16.09	**71.54**	8.65

Table 8: XYZ Analysis for Year 2013-14

(IAI's Dornier Aircraft Servicing)

Class	**Stock Holding**		**Non Moving**	
	No of Items	**Value in Rs. Lakhs**	**No of Items**	**Value in Rs. Lakhs**
X Class (Above 5 Lakhs)	264	3534	0	0
Y Class (2 to 5 Lakhs)	286	643	16	91.2
Y1 Class (1 to 2 Lakhs)	918	893	172	192.2
Z Class (> 1 Lakhs)	3690	480	1868	121.5

The analysis in the table brings out the factual position as well as trend in movement of inventory during the year, thus projecting the number of items which remained unmoved since. Constant monitoring of the items with proper physical checking with part numbers and similarities along with reviews with OEM's during the year have resulted in bringing down the number of items as well as non moved items in X and Y category (High Value Density). This shows that trend in non-moving items is healthy as very few items are there in this category having no movement. In the analysis report for on-line checking with IFS/ ERP system at IAI, the last issue/receipt date is also inserted in the RFID tag information to give a better idea of the movement in the items. Issue control was strictly followed for avoiding further addition to the inventories following FIFO method with strict control of shelf life items.

From the above tables it may be inferred that the high value items are planned properly and were put to use within the time schedules, there by the non-moving items in the X class are Nil. Also the X class items cover only 5.12 percent of the items in the year 2013-14.

For effective monitoring of the stock holdings XYZ Analysis and ABC Classification are used in conjunction with combinations such as AX,BX,CX; AY,BY,CY etc. This technique is highly useful in identifying the items which are extensively stocked. Similarly XYZ and FSN classification as detailed in earlier pages is also highly useful in controlling obsolete items

Fast, Slow & Non-Moving Analysis

This analysis is based on the movement of the items. FSN analysis is especially useful to combat obsolete items whether spare parts or raw materials or components. FSN classification of spare parts and equipments is being done in IAI with the following thumb rule.

1. If the item moves in a year with constant consumption, and monthly issues, it is said to be fast moving item.
2. Items having limited issues during 24 months are categorized under slow moving items.
3. The items which are in stock without being issued/used for more than two years are characterized as non-moving items.

In IAIs fast moving items were 6040 (The total of A B B1 and C) in number as on 31.03.2014 for one aircraft – Dornier-228. The consumption value during the year for these items is Rs. 6648 lakhs with the stocks accounting for Rs. 5550 Lakhs and constitute for 304 days stock. They are further analysed under ABC analysis. The Non Moving inventory as on 31.03.2014 was Rs. 404.9 lakhs (2056 items). The total slow moving inventory as on. 31.03.2014 was Rs. 1984 lakhs and there were 1811 items accounted to this category. The slow moving items have been reclassified under SX,SY, SY1 & SZ for achieving better utilization of items.

SX – Slow moving 'X' class items.

SY – Slow moving 'Y' class items

SY1 – Slow moving 'Y1' class items.

SZ – Slow moving 'Z' class items.

The SX, SY and SZ analysis, which is being followed is helped in avoiding the addition of Slow Moving Inventory to the Non Moving Inventory. A monthly review Meeting on the Slow Moving items with User departments is held regularly for this purpose to understand the technical reasons behind non-utilization viz., Change in Design, New Version or Modified version received, Change in parameters by OEM's, Item is giving good life on Aircraft, Repair facility Outsourced, Repair facility made available in-house, change in part identification numbers, alternate usage etc.,

Table 9: FSN Analysis Of Items Used On Aircraft

(IAI's Dornier Aircraft Servicing)

YEAR	FAST MOVING ITEMS		SLOW MOVING ITEMS		NON MOVING ITEMS	
2009-10	2435	19.83%	4028	32.80%	5817	47.37%
2010-11	2543	21.67%	3801	32.39%	5392	45.95%
2011-12	2814	24.45%	3581	31.11%	5116	44.44%
2012-13	2532	24.86%	3223	31.64%	4431	43.50%
2013-14	2813	25.46%	3884	35.15%	4353	39.39%

From the FSN analysis table it can be inferred that the Fast moving and slow moving items are on increase, and Non moving items are showing reduction trend. It may be inferred that the items that can be useful interchangeably were put to use so that the Non Moving items got reduced. Also from the constant trend of slow moving inventory in the last few years, it may be inferred that most of the items purchased were not put to use within one year. Also few of the items were not at all used in two years period and obsolescence may also increase at this rate. Hence strict controls are to be envisaged to curb the Non Moving Inventory and to avoid items becoming non-Moving. Items which were stock piled for future needs and purchased with strategic planning for specific reasons were not considered and were tagged separately as "Stock Piled Items'.

Non Moving Inventory Analysis

The value of non moving items (unmoved for more than 2 years) as on 31.03.2014 was Rs. 404.9 lakhs which spread over 48 main groups consisting of 2056 items. In addition to these there are 3884 items valued at Rs. 203.64 lakhs under slow moving category of more than one year but less than two years as on 31.03.2014. All these items were analysed with a view to utilize them in a better way and to reduce the number of items and value in the category of non-moved items, using various stock utilization techniques. When stocks are available and replacement was not made on aircraft for long periods were identified and parts have been utilized to improve the utility of the item after technical review.

For achieving the reduction, action had been taken in phase-wise under the following heads.

a) NX-Class……(Non-moving X-Class)
b) NY-Class……. (Non-moving Y-Class)
c) NY1-Class… (Non-moving Y1-Class)
d) NZ-Class…… (Non-moving Z-Class)

The above table also shows that the Non Moving Inventory has come down to 39.39% of the total and is the optimum level when servicing Aircraft Norms are considered as per IAI. From the table it is also confirmed that the items under high value categorization got better control and no unmoved item is existing in this category.

The items are analysed with the help of IFS/ERP Systems software on regular basis. The computerized analysis played a vital role and because of which the NON MOVING inventories were physically identified and action plans for the future has been drawn for constant weeding out of these Non Moving Inventories.

Scrap, Surplus & Obsolete Items Analysis

Surplus is not an inspiring word. It often brings to mind thoughts of old pup-tents, mess kits, and world war – II gas masks. Even industrial surplus seems to imply mistakes in over procurement, wasteful production process, and inefficiencies in general. To make matters worse, surplus frequently seems to be associated unglamorously with "Junk" and scrap heaps. Because of these facts, surplus is not an enchanting business activity; consequently it frequently does not receive the management attention it deserves. This is regrettable, because in the Indian Aircraft Industrial system the total cost of Aircraft Servicing is the sum of the costs of labour, materials, and overhead minus any returns from the successful sale of all kinds of Surplus & obsolete and scrap materials. Profits are maximized only when all elements affecting cost are fully controlled.

In such a situation, IAI has evolved a strategy for quick disposal of surplus, obsolete and scrap materials.

All items not in regular use at Servicing Stations and not expected to come into use as per best anticipation in the future of up to two to five years have been classified under the following heads:-

a) Scrap Items
b) Obsolete Items
c) Non-moving/slow moving items
d) Overstock items
e) Surplus items

The basis of items classification under the above heads is as under:

Overstock Items

When stocks on hand of an item exceed the requirements for next 24 months (for spares) and 12 months (for other items) the quantities in excess of the above limits are termed as "overstock". This has not been applied to 'C' class items for which the minimum economic purchase quantity may itself exceed the above limit. For 'C' class items stocks in excess of the two times of the Economic Order Quantity would be termed "overstocks".

Surplus items

Inactive items as defined above held in stock for which 'no use' in IAI Servicing Stations can be foreseen during the next 24 months are categorized as surplus items.

Weeding-out Surplus/Obsolete/Scrap Items

Scrap and obsolete items are sold by Tendering. Non-Moving, overstock and Surplus items are re-checked with current production and manufacturing needs and utilization by modification, if feasible. The lists of Surplus, Obsolete, Non-Moving & Overstock items are made into specific lists and were circulated to all departments and units/ sister concerns in LAN-WAN System for avoiding purchase of similar or same parts at the manufacturing and servicing units.

The lists would be given with full data such as Manufacturer's details, Manufacturer's part numbers, alternate part numbers and next assembly/sub-assembly details, shelf life/re-life condition etc., so that proper utilization action can be planned. None of the sister concerns or manufacturing units in IAI are supposed to buy the items that appear in these consolidated list made available with various sub-groups and the IFS/ERP system would indicate such information up-on preparation of Bills of Materials/ SOP/Servicing Plan.

V E D Analysis

Under this analysis, the classification is based on whether the item is vital, essential or just desirable. It is mostly applicable to spare parts/ Rotables/ and LRU's.

Vital	Essential	Desirable
Reasonably Large Stocks held as per SOP (Standard of Preparation)	Exact Quantities held as per Servicing Requirements	Low or Nil Stocks held

Greater Attention	Adequate Attention	Periodic Attention

Class	Vital (V)	Essential (E)	Desirable (D)
A	Constant Control Limited Stocks	Moderate Stocks	NIL Stocks
B	Moderate Control Moderate Stocks	Moderate Stocks	Very Low Stocks
C	Loose Control and High Stocks	Moderate Stocks	Low Stocks

The Categorisation is made based on the importance or criticality of the item to the machine.

For best results, it is the practice to consider these three levels of criticality (VED) in combination with the three levels of annual usage value (ABC). The combined decisions for maintenance of service levels for better understanding can be represented on a contingent matrix.

CLASS	*V*	*E*	*D*
A	126	68	18
B	288	398	29
B1	324	436	98
C	1280	1122	1200

From the analysis it is observed that there were very few items under the head AD and good number of items in AV class items. AD can be made near to ZERO and continuing strict monitoring of AV items with optimum control will be helpful in reducing the inventory and to release the tied up working capital.

Rotables Management

Aircraft manufacture and maintenance sector need perfect management of Rotables that are used on the Aircraft with Integration of Supply Chain for meeting the needs of the customer and to save Aircraft on Ground (AOG) situations. The class of inventory referred to as 'rotable' is not a spare part that get consumed, rather parts are repaired and returned to stock for the lifetime of the aircraft fleet. This type of inventory is not well supported by mainstream ERP application functionality.

A new algorithm has been developed for this special inventory from the existing standard algorithms by the author for an improved solution to the rotable planning task at IAI. This solution uses an integer linear programming formulation, different from normal practice and normal thinking and this system aims at optimization of the entire stock of inventory as a single problem, rather than a series of smaller optimizations at the line item level.

A small sample problem is presented to illustrate the solution and compare it with normal practice at IAI. The problem formulation is expressed as a global optimization objective function with a set of constraints, which is simple for implementation by any of the industries in the similar lines of operations. Rotable stock needs to be managed differently to consumable material. While there have been some systems developed for this problem, usually looking at the problem of dividing inventory around several aircraft, specialist solutions are not in widespread use in the industry. The standard model followed by ERP inventory systems takes manufacturer's guideline reliability data for each part number and makes a calculation based on several factors. The calculation is performed using proprietary solutions; the example below is from IAI's DORNIER Aircraft and is produced using an iterative probability calculation-

Recommended holding for part 2018-A-01 = f(MTBR, TAT, QPA, FleetUtil, SL) = 8

Where:

MTBR = 2,314 hours

(Mean Time between Removals)

TAT = 30 days

(Turn Around Time: time taken to route, maintain and replace the item in inventory)

QPA = 1

(quantity per aircraft)

Fleet Utility = 53,229hours in the past 365 days (total hours flown by the total number of aircraft of the same type)

SL = 95%

target service level: (the probability of the part being available)

The calculated number will be a quantity of a given part number: for example, the recommended holding level for a cabin pressure controller (part number 2018-A-01) is 8, to satisfy 95% of requests for part number 2018-A-01.

No account is taken of the time taken to order a new item as the items are maintained as opposed to consumed. This means that ordering costs and economic ordering cost quantities are not needed in this calculation, since they have no bearing on the number of items needed to support operations. Since the actual time at which a part is needed is stochastic, a probability distribution is used to determine a realistic holding. The Service Level (SL) is the probability of a part being available: a SL of 95% means that there is a 95% probability of the part being available at any time, given the stated utilization parameters.

To guarantee 100% SL would require a full duplication of all items in service, which is excessively costly. In practice, a target SL of 95% is used for essential items (parts without which the aircraft cannot operate, and are referred to as ‘no go’). There are lower SLs for ‘go if’ items (e.g., one radio may be unserviceable if two others are working) and ‘go’ items (e.g., galley equipment, which the aircraft can operate safely without).

A cumulative Poisson distribution is used to calculate the probability of requests for parts being satisfied: in the above example, the probabilities of 0, 1, 2, 3 ,4, 5, 6, 7 or 8 parts being available exceeds 95% for the given rate of demand. Using this method, a calculation is made for each line item in turn It was proposed that the conventional approach was deficient in its analysis since it considers individual line items (stock keeping units (SKUs) / part numbers) without regard to the other items. This highlights two major factors when considering IAI's Rotables supply chain optimization:

- The relative cost of parts: it is more acceptable to delay the despatch of an aircraft for a US$100,000 dollar part than for a US$100 part in case of imported one. Typically inventory-planning calculations take no account of relative cost and impact on availability. However, it makes sense from an operational perspective to manually manage low stock levels of very expensive items, while providing greater levels of safety stock for less costly items.
- The relative failure rates of parts: rather than calculate failure rates at the individual part level, the real business problem is to maximize the number of requests satisfied for spares, regardless of the part number. In other words, each time a request is made to stores, there is a required probability of 95% that it be fulfilled. This is quite different to the traditional objective of having a given part available 95% of the times that it is requested.

Thus the objective of the inventory planning function changes: the old objective function (sum of minima) is replaced by a global objective function (minimal sum) in IAI. The new problem statement can be solved as a linear program. The difference between the line-by-line approach and the linear programming solution is shown by the data in Table I using a sample of 5 parts with Part Nos- 2018-A-01-3 to 2018-A-01-7. (These were mentioned as 3,4,5,6 and 7 for simplicity). Table I shows individual line item calculations with target service level exceeded by the numbers highlighted with a box: for the first part, a SL of 92% is attained with 9 units, exceeding the target SL of 90%. Similarly, values of 3, 2, 3 and 4 are computed for the remaining parts respectively.

The new solution, the linear program, derives a solution to give a service level of 90% for the group of parts, i.e., for all requests for parts, 10% will fail. The LP solution gives lower values for 3 of the 5 parts in the example in table 10. The old solution values are in italics, new solution values in bold. In order to solve the LP, SL calculations as in Table 11 are performed up to a limiting number of values, which is established by trial and error. Thus in Table 11 SL is calculated up to a limit of 15 for each line item. Another pre-processing stage is to compute the extended cost for each quantity. The difference in total inventory cost for this sample, while maintaining the target service level for the fleet, is shown in table 11 below. (Same sample of 5 parts with Part Nos- 2018-A-01-3 to 2018-A-01-7. (These were mentioned as 3,4,5,6 and 7 for simplicity).

TABLE 10: Recommended Quantity For Stock Holding – IP Solution

TABLE 10 RECOMMENDED QUANTITY FOR STOCK HOLDING BY OLD AND NEW METHODS															
	Target Service Level = 90%						OLD SOLUTION					LP SOLUTION			
PART NO	DESCRIPTION	PRICE	MTBR	CALCULATED SERVICE LEVEL % FOR QUANTITY											
				1	2	3	4	5	6	7	8	9	10	11	12
2018-A-01-3	TACHO GENERATOR	112200	3500	2	6	17	31	46	63	76	86	92	96	98	99
2018-A-01-4	IGNITION EXCITOR	71450	22000	62	85	95	98	99	99	99	99	99	99	99	99
2018-A-01-5	PUMP	67000	20000	89	90	99	99	99	99	99	99	99	99	99	99
2018-A-01-6	HIGH STAGE REGULATOR	75000	9000	57	81	93	98	99	99	99	99	99	99	99	99
2018-A-01-7	BLEED AIR REGULATOR	170500	5700	36	63	82	93	97	99	99	99	99	99	99	99

TABLE 11: Recommended Quantity For Stock Holding Proposed IP Solution

TABLE II RECOMMENDED QUANTITY FOR STOCK HOLDING COST OF OLD AND PROPOSED SOLUTIONS								
	Target Service Level = 90%				OLD SOLUTION			LP SOLUTION
PART NO	DESCRIPTION	PRICE	QTY OLD METHOD	Total Cost Old Method	Qty by LP	Total Cost LP	Cost Differential	Remarks
2018-A-01-3	TACHO GENERATOR	112200	9	1009800	9	1009800	0	
2018-A-01-4	IGNITION EXCITOR	71450	3	214350	2	142900	-71450	cty 1
2018-A-01-5	PUMP	67000	2	134000	1	67000	-67000	cty 1
2018-A-01-6	HIGH STAGE REGULATOR	75000	3	225000	3	225000	0	
2018-A-01-7	BLEED AIR REGULATOR	170500	4	682000	3	511500	-170500	cty 1
Total 5 Items				2265150		1956200	-308950	-14%

The detailed linear programming problem formulation can be stated as follows-

$$\text{minimise} \sum_{i=1}^{n} cost_i$$

subject to
1. global service level $\geq$ target service level

2. $\sum_{j=1}^{UL} X_{ij} = 1$ each row sums to 1

where i = part number, $1 \leq j \leq UL$,

UL = upper limit quantity, e.g., 15

3. $X \in \{0,1\}$ X is a binary value

This solution has been tested with a selection of 300 parts from a Maintenance, Repair and Overhaul inventory holdings of the customer and their physical stock position. The actual holding was valued at Rs.10.8 millions. The LP solution recommended a holding with a value of Rs. 6.4 million to achieve the same service level. There is thought to be some inventory which exceeds the old method recommended levels (over-stocking) so the theoretical improvement is expected to be less than 40% and more in line with the 14% gain shown in the 5-part example above. Further testing has been carried out and all the results show the same or similar advantage.

Solution through Neural Network

In the past, one of the de-facto assumptions for inventory management was that the demand pattern follows a specific distribution function. However, it is improper and inappropriate to apply this assumption in real situations because the demand information in the supply chain tends to be distorted due to the bullwhip effect in a supply chain especially in Aircraft Industry. To overcome this weakness, IAI applied a new solution method using NN (Neural Network). This method proceeds in three steps. First, it find the patterns of optimal reorder points by analyzing past data. Second, trains the NN using these pattern data and finally decides the reorder point. Using simulation experiment, it can be proved that the IAI's new system solution gives better result than that of traditional approach.

With the improvement of modern information technologies, the real - time stock information of the supply chain members – all the IAI units, divisions, sub-stores and customers, is available through the net working LAN-WAN. Therefore, the reorder policy based on the real -time centralized stock information apart from Inventory Analysis considering all the echelons of the system is crucial. It can be seen from the reorder policy for a continuous review 'batch – ordering' in two - echelon distribution system, utilizing the centralized stock information and the efficient stock taking and improved service level to the supply chain members. Existing reorder policies with IAI are classified into installation stock policies and echelon stock policies.

Installation stock policies determine the reorder time based on installation stock, which is inventory position at a certain installation. Thus installation stock policies do not utilize additional information of other facilities. Echelon stock policies are based on echelon stock. The echelon stock is defined as the sum of the installation stock at the considered installation and at all its downstream installations.

The echelon stock policies in IAI utilize the centralized stock information. Both policies have been commonly used for multi-level inventory systems. In serial and assembly systems, it has been seen that echelon stock policies are superior to installation stock policies. On the other hand, in distribution systems, echelon stock policies do not always outperform installation stock policies, and both policies may be far from optimal.

However, both policies have been also commonly used for distribution systems at IAI especially for Design Stock Piling, Spare Parts bank Control, Production/servicing stores (sub-stores) and Customer Stock-nets. Especially, echelon stock policies have been often used in the situation where centralized stock information is available.

It is undesirable to apply the assumption that the system follows poison's distribution or normal distribution in real situations because the demand pattern in Aircraft Servicing Industry's supply chain may not follow the defined distribution.

To overcome this weakness, the new solution using NN (Neural Network) is being used in IAI. Analyzing past data and then training the NN using these data, one can find the reorder points even if the demand pattern does not follow the Poisson distribution or normal distribution.

NN Model

The continuous review system with two -level inventory with *N sub-stores* facing independent stochastic demand as being followed by Indian Aircraft Industries is explained in Figure-1.

The servicing hanger's sub- stores orders the items for Aircraft servicing with the required quantities in batches and the lead-time is generally constant. Similarly, the central warehouse/store replenishes its stock by progressive ordering system in batches from a Foreign Vendors or Indian Source, through normal purchase route.

The Lead-time (import/transportation times) including Vendor's lead time for such deliveries is also constant. Unfilled demands are backordered and the shortage cost is a linear function of the time until delivery. Orders or parts of orders that cannot be delivered instantaneously from the warehouse/central stores are ultimately delivered on a first-come - first-serve basis. There are linear holding costs at all locations.

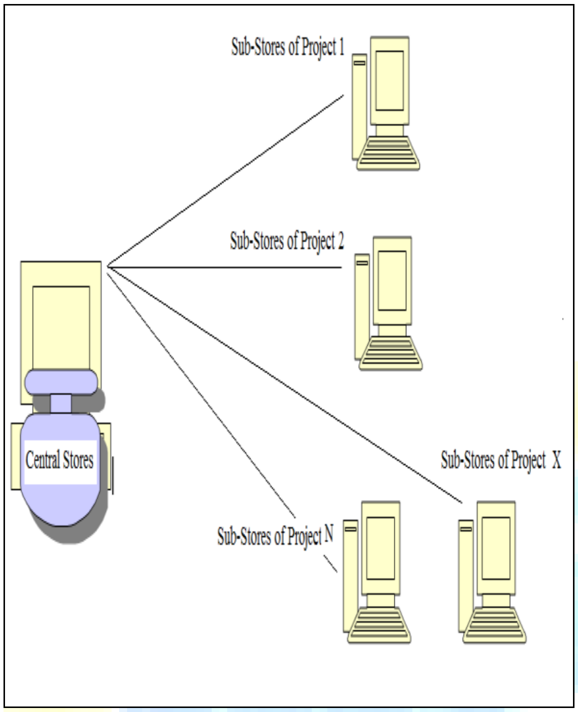

Figure 1 - One Central Stores and multi -Sub-stores/ Divisional Stores of different projects - inventory Model

Given these assumptions, the costs are determined exactly for different policies. These cost expressions can then be used for the efficient determination of reorder policy.

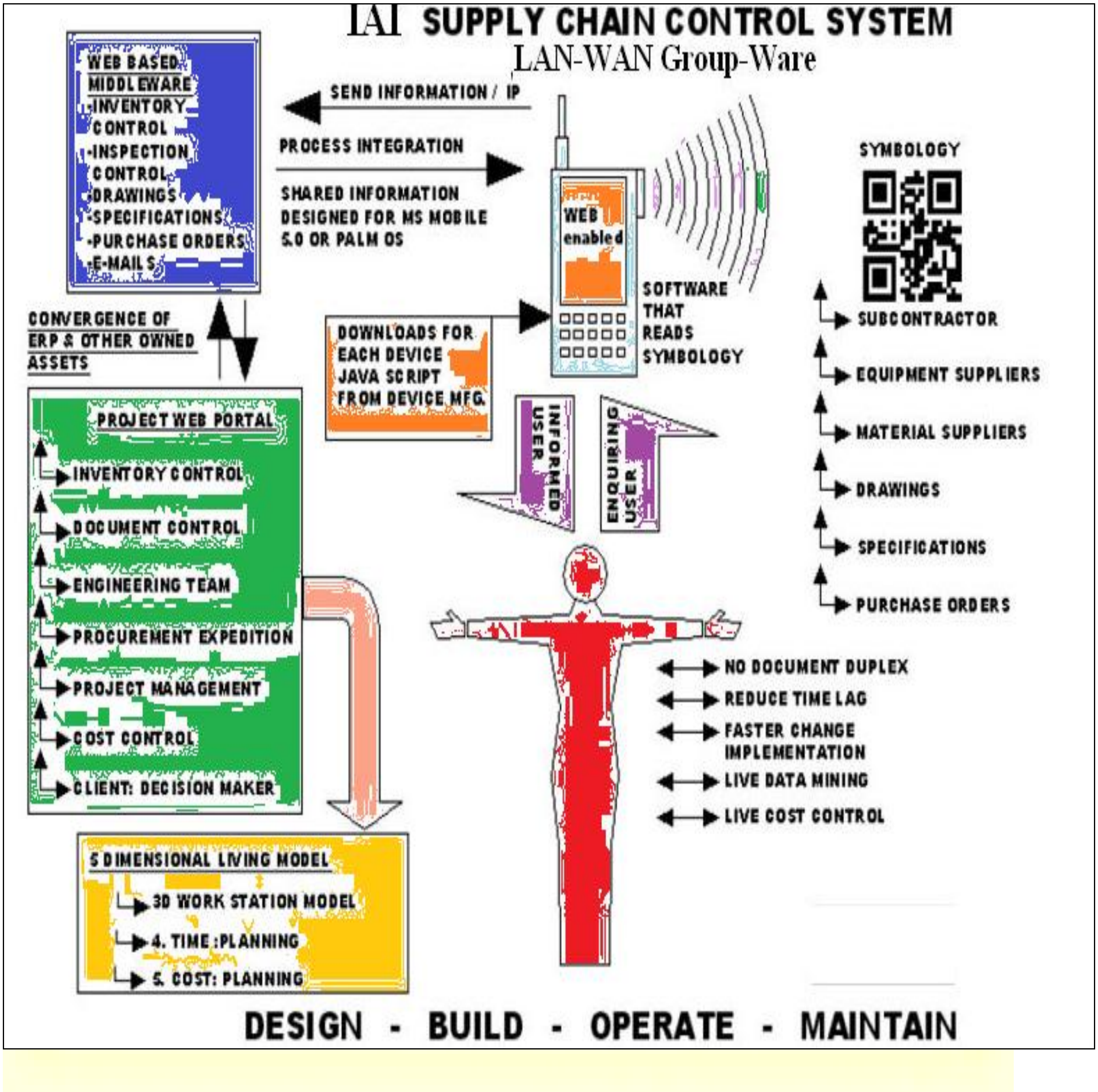

Chart 1: IAI's Supply Chain control System through LAN-WAN Group-ware

For notational convenience, it is referred as the Central Stores as facility 0 and Sub-stores/ Divisional Stores 'i' as facility *i*, i=1,2,……,*N*.

N : number of retailers

L0 : lead time from the outside supplier to the Central Stores

Li : lead time from the Central Stores to retailer

li : customer demand rate at Sub-stores/ Divisional Stores *i*

hi : unit inventory holding cost rate at facility *i*

pi : unit stock-out cost rate at facility *i*

*Ki : f*ixed ordering cost at facility *i*

Qi : base order quantity at facility *i*

Ri : reorder point at Sub-stores/ Divisional Stores *i*

i0 (*t*)*:* installation stock position of the Central Stores at time *t*

ri (*t*)*:* relative inventory position of Sub-stores/ Divisional Stores *i* at time *t*

r(*t*) *:* relative inventory position vector at time *t*, i.e.

$(r_1(t), r_2(t), \ldots\ldots, r_N(t))$

$l_0(t)$: installation stock level of the central STORES at time t

$\Omega_0(t_1, t_2)$: ordering quantity of all Sub-Stores during (t_1, t_2),

$\Omega_i(t_1, t_2)$: ordering quantity of Sub-Stores i during (t_1, t_2)

$D_i(t_1, t_2)$: customer demand at Sub-Stores i during (t_1, t_2),

Order Risk Policy

By considering a two -level inventory system with one Central Stores and N sub-stores at Servicing Stations at IAI this system is formulated. N Divisional Stores apply different continuous review installation stock (R, Q) policies.

The Divisional Stores face independent demand processes. The main issue of this problem is to find the continuous -review batch - ordering inventory control policies at the warehouse/ central stores and Reorder Decision Support Function (RDSF) as the function of which value is the basis for the reorder decision.

Then any continuous -review batch ordering policy can be said to be a policy that an order is issued when the value of RDSF is below a certain value, i.e. reorder point. Installation stock policies use installation stock position as RDSF, and echelon stock policies use echelon stock position as RDSF. By denoting installation stock position of facility *j* as *ij* , where *j*=0,2,…,*N* and *N* is the number of retailers. Let *i0* represent the installation stock position of the Central Stores.

Then the RDS F of installation stock policies

(g_1) can be written as $g_1(i_1, i_2, .., i_N) = i_0$

and the RDSF of echelon stock policies (g_2) is

as $g_2(i_1, i_2, .., i_N) = \sum_{j=0}^{N} i_j$

As shown above, echelon stock policies consider more information than installation stock policies. However, in spite of additional information, it is known that echelon stock policies may show an inferior performance to installation stock policies in certain distribution systems.

The reason of this problem lies in the way the centralized stock information is processed. Echelon stock policies utilize the centralized stock information through the sum of all the inventory positions. However, aforementioned problem says that the sum of inventory positions may produce a distorted observation about the system status. Thus, it is necessary to design an RDSF that processes the centralized stock information more effectively, resulting in an accurate observation of the system status and an improved inventory control.

As per the concept of order risk and order risk policy at each moment, one should determine whether to order immediately or to delay the order. For that decision, one needs to quantify the risk of immediate order.

The order risk represents the relative cost increase due to immediate order, compared to delayed order. Let t be the current system time, and e be a very short time during which no system demand occurs. If it delays the order by e rather than order immediately, it can expect holding cost reduction and penalty cost increase. This concept is displayed in Figure 2.

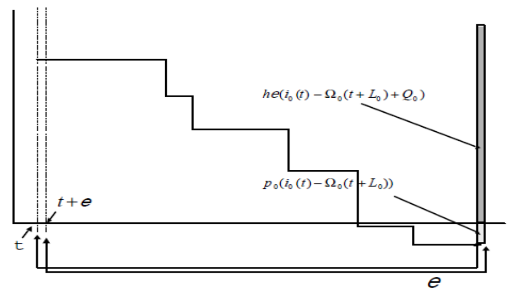

Fig .2 Cost savings of delaying order by e

If the warehouse orders at t, the stock level at $t+L_0$ becomes

$$I_0(t+L_0)=i_0(t)-\Omega_0(t+L_0)+Q_0$$

If the warehouse orders at t + e

$$I_0(t+L_0)=i_0(t)-\Omega_0(t+L_0)$$

and

$$I_0(t+L_0+e)=i_0(t+e)-\Omega_0(t+e,t+L_0+e)+Q_0$$
$$=i_0(t+e)-\Omega_0(t,t+L_0)$$

since no system demand occurs during e.

If $i_0(t)-\Omega_0(t+L_0)>0$, the warehouse can get net cost savings of $h_0Q_0\ e$ since holding additional stock Q_0 is delayed by e. If $i_0(t)-\Omega_0(t+L_0)\le -Q_0$ delaying order by e incurs penalty cost increase of $p\ e\ Q_0$.

When $Q_0\le i_0(t)-\Omega_0(t+L_0)\le 0$ by delaying order, both holding cost savings and penalty cost increase, thus net savings on system cost becomes

$$h_0(i_0(t)-\Omega_0(t,t+L_0)+Q_0)+p_0(i_0(t)-\Omega_0(t,t+L_0))$$

By taking $e\to 0$, we can get the marginal value.

Thus, the marginal saving of delaying order which means order risk, denoted by $\rho(i_0(t),\Omega_0(t,t+L_0))$ is

$$\rho(i_0(t),\Omega_0(t,t+L_0))=\begin{cases}h_0Q_0\\ h_0(i_0(t)-\Omega_0(t,t+L_0)+Q_0)\\ +p_0(i_0(t)-\Omega_0(t,t+L_0))\\ -p_0Q_0\end{cases}$$

Order risk policy is the reorder decision policy which is based on the order risk. If the value of the order risk is positive, it is beneficial to delay order. Negative value of the order risk indicates that an order should be issued immediately. The RDSF of the order risk policy can be described as $g_3(i_0,i_1,\ldots,i_n)=E[\rho(i_0,\Omega_0)]$ where $\rho(i_0,\Omega_0)$ is cost savings of delaying order.

The calculation of $E[\rho(i_0,\Omega_0)]$ is not easy if it assume demand pattern does not follows Poisson distribution. Since NN are universal and highly flexible function approximations, it can be found RDSF of the order risk policy without assuming the demand distribution.

Back-propagation 'Neural network'

Back-propagation (BP) of neural networks consists of collection of inputs and processing units known as neurons. The neurons in each layer are fully interconnected by connection strengths called weights which along with the network architecture, store the knowledge of a trained network.

In addition to the processing neurons, there is a bias neuron connected to each processing unit in the hidden and output layers. The bias neuron has a value of positive one and would serve a similar purpose as the intercept in regression models. BP networks are a class of feed-forward neural networks with supervised learning rules.

Feed-forward refers to the direction of information flow from the input to the output layer. Inputs are passed through the neural network once to determine the output. In this model, a simple back propagation neural network using a sigmoid transfer function will be constructed along with three fully interconnected layers. (Fig 2) The input layer has a node for the inventory level of Sub-Stores and Central Stores. The size of the middle layer is 80% the number of input layer nodes. The output layer has just one node whose value indicates the order risk at the given inventory situation.

Training data for learning can be obtained by history of issues – consumption data. Since future demand is stochastic, one should find expected value of order risk to calculate current inventory status.

But if one knows the demand pattern, order risk value is not random variable any more. The exact order risk value can be easily calculated. Table below shows example of test training data-

Table 12 Example of test data

Time	W	R1	R2	R3	R4	R5	R6	R7	
10.4	-50	47	14	28	39	42	45	10	972
11.2	-50	47	14	28	39	42	44	9	590
13.1	-50	47	14	28	38	42	44	9	-210

The status of inventory in the supply chain and order risk value at that time are given in the table. Similarly the order risk value of each inventory status by analyzing past data can also be calculated.

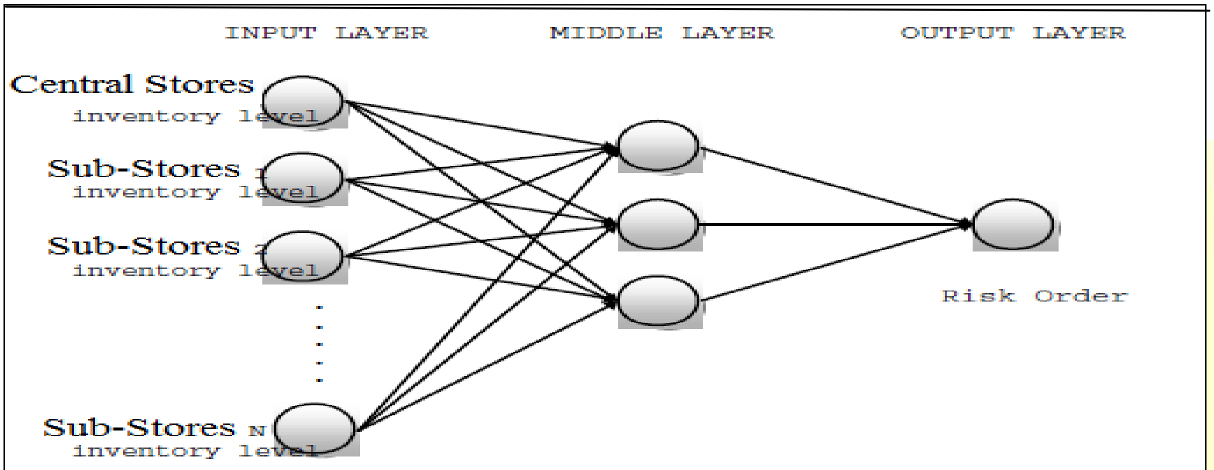

Figure .3 Backpropagation Model

The training process used 35% as the learning rate and 90% as the momentum term, and trained for maximum of 2,000 iterations of the training set keeping the weights that performed best on training set. All history data in the test set were presented to the network.

Computational Experiment

Through the computational experiments for 80 numerical examples, it has compared the 4 policies, installation stock policy, echelon stock policy, order risk policy I which assumed demand pattern follows Poisson distribution, order risk policy II which use NN.

Since the cost of retailers is not affected by the Central Stores operation, it has compared only the cost of the Central Stores. In the test cases, set $Q0=100$, $h0=1$, $p0=10$ and $Qi=50$, $hi=2$, $pi=50$ for $i>0$, $N=4$ and initial Central Stores inventory level to be 0.

It assume demand pattern follows compound poison distribution. Set average of the each Sub-stores/ Divisional Stores's demand as

$$\mu_i \in \{2,2.5,3,3.5,4,4.5,5\}$$

and variance as

$\sigma_i \in \{0,5,10,15,20,25,30,35\}$

Figure below shows that the average cost reduction by adopting the order risk policy II than the echelon stock policy and the installation stock policy is 33 and 56%, respectively, for the test cases, and the cost difference between the order risk policy-II and the existing policies is statistically significant with 95% confidence level. Figure below shows that order risk policy II outperform order risk policy I. Maximum 25% cost reduction can be obtained using order risk policy II.

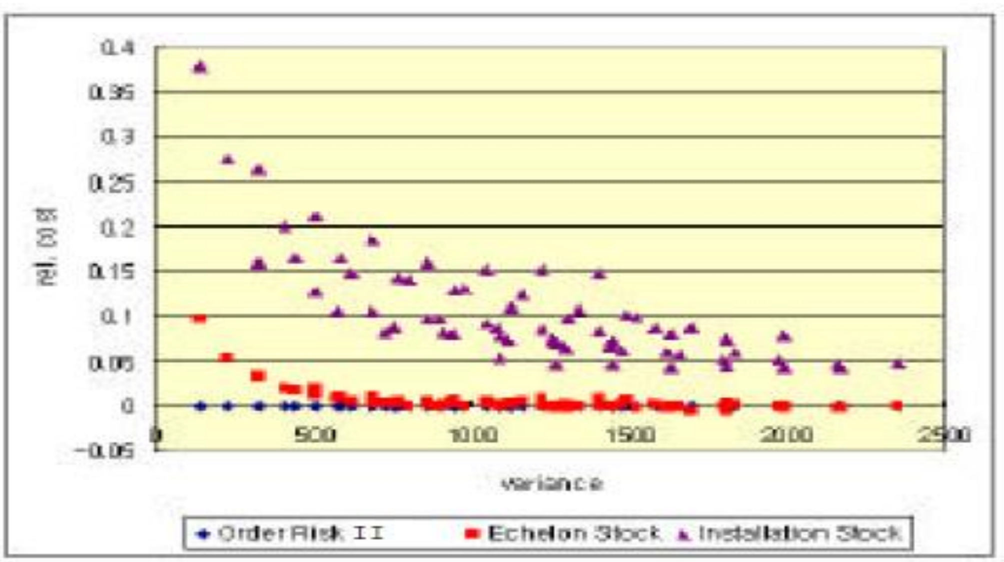

Figure 4 Cost difference with variance

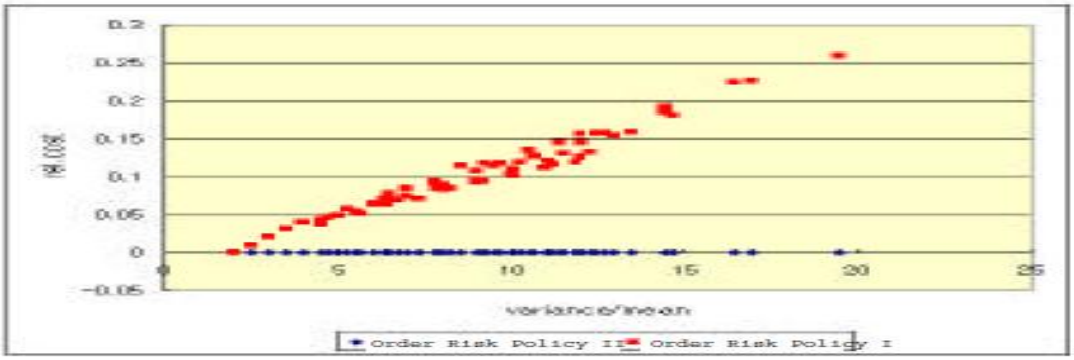

Figure 5 Cost difference with Order Risk Policy I

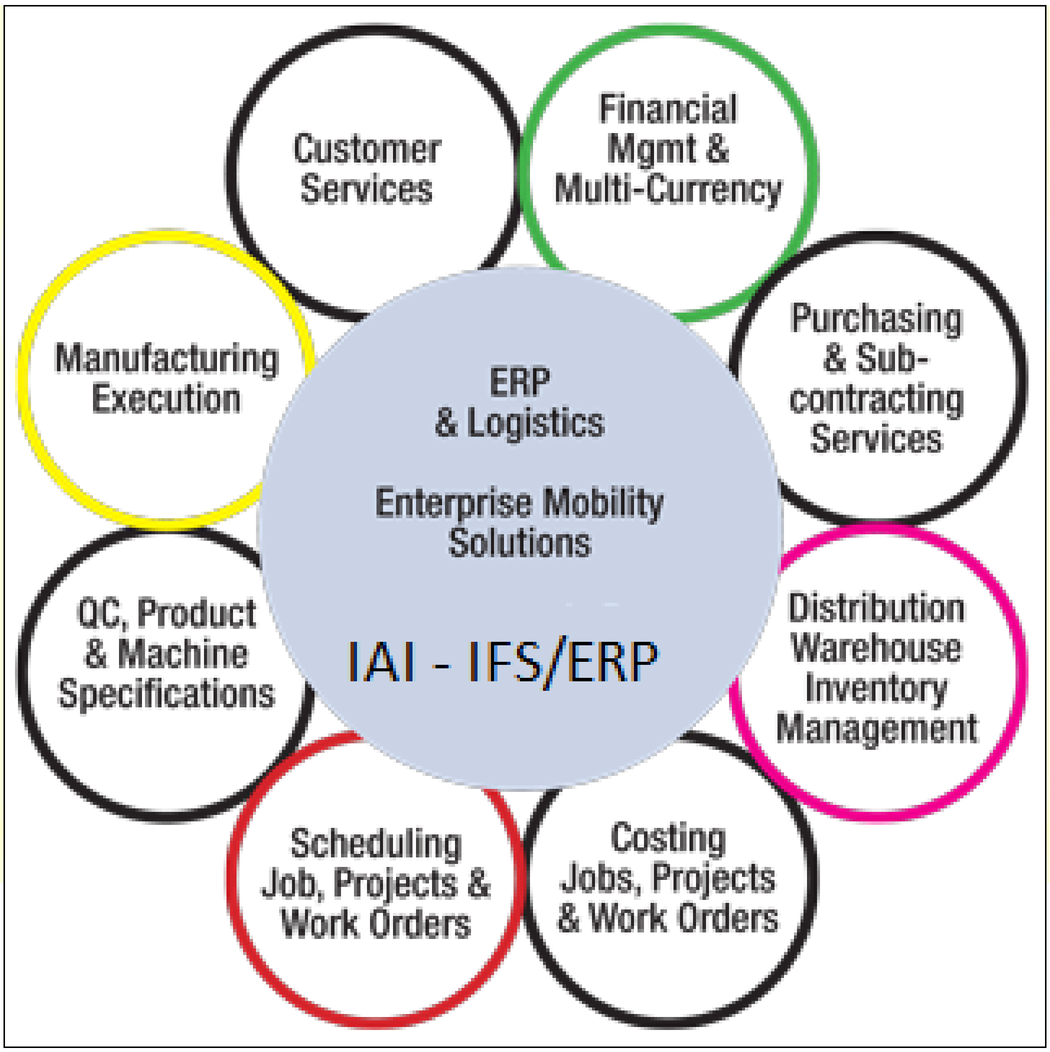

Figure 6: IAI'S IFS/ERP Solutions

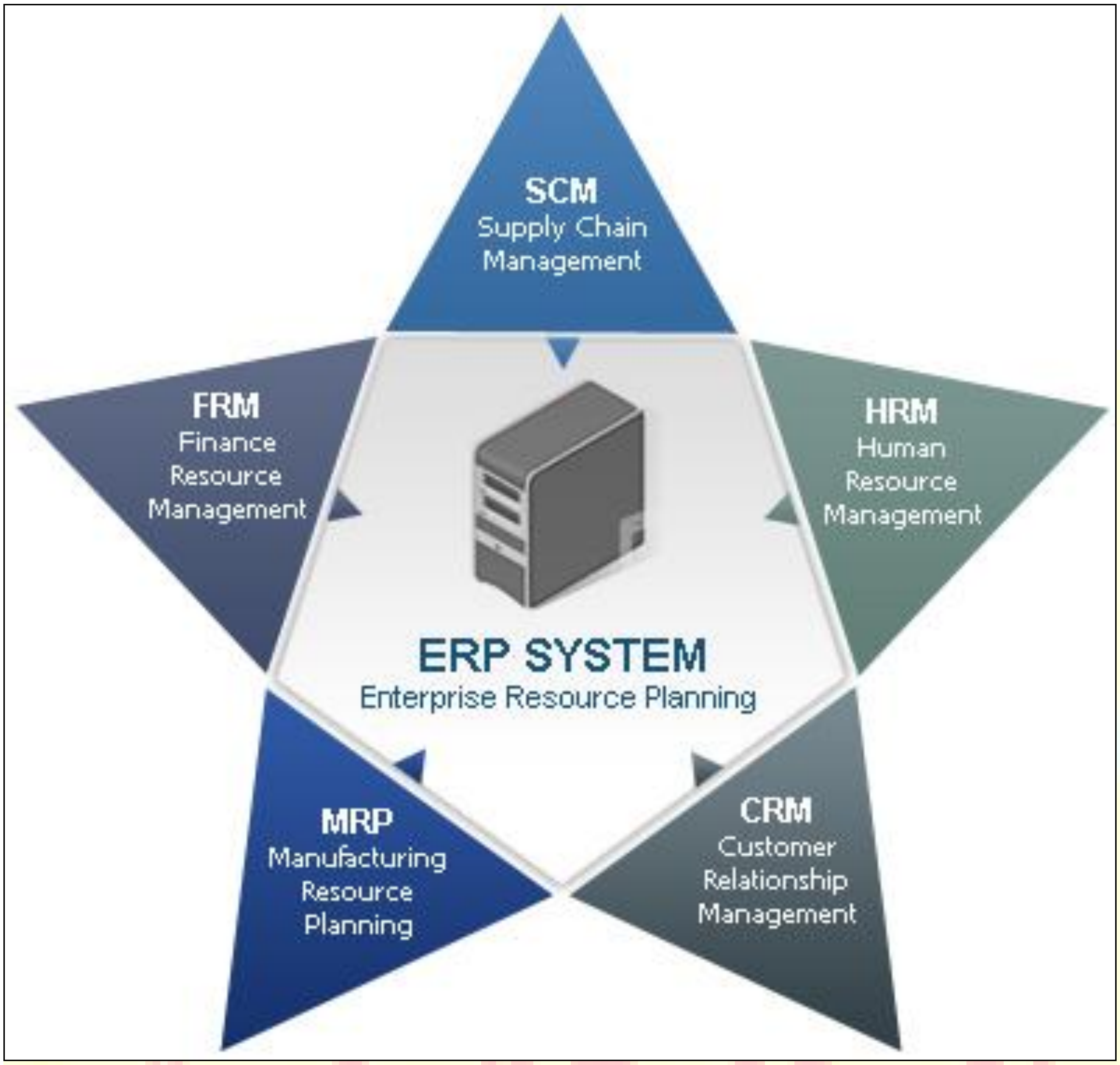

Chart.2. IAI's Enterprise Resource Planning System – IFS/ERP

Thus the IAI'S developed order risk policyII using NN is having multiple advantages. The major advantage of this method is that it can find reorder point using all the information in supply chain regardless of assuming demand pattern (Stochastic case). Computational experiments comparing the order risk policy II with existing policies show that a significant cost reduction can be obtained by adopting the order risk policy II.

The IFS System in Neural Net-working

The neural networking was done through IFS in Indian Aircraft Industries and IAI meets global competitive industry demands through IFS Applications. Following its implementation of IFS

/ERP Applications combining all echelons, IAI has standardized its processes across all the divisions/units. Software package driven Business Process Re-engineering (BPR) exercise is also carried out throughout the organization with the help of IFS/ERP Applications. Inventory analysis is also finally done with total integration so that all divisions' inventories are taken into consideration for identifying stocks, re-ordering and deciding Order Quantity and staggered deliveries requirements. The Inventory Module in IFS/ERP takes care of the following-

- MPS - Master Production Schedule, Master Servicing Schedule, MRPII - Material Requirements Planning and AAPS – Aircraft Advanced Planning and Scheduling.
- Maintenance/Service - Execution System and Product Data Management with individual Aircraft being received for Servicing.
- Budgetary Estimations, On-line progress linkages- Equipment replacement Schedules-Inventory Analysis.
- Visual Schedule Board for Aircraft Delivery Progress.
- Customer Services, EDI and Customer Information. Automotive Part Release - Design Database for Modifications.
- Distribution Warehouse Inventory Management
- Scheduling and Costing of Jobs, Major Servicing Schedules – Overhaul parametric.
- QA, QC, Product and Machine Specifications, Testing and Test History – Traceability of the part in Aircraft fleet.
- Customers Stocking Points and Servicing Points at various locations with-in India.
- Preventive Maintenance and Repair Order Scheduling, Costing with Repair/Cost History by machine, equipment and Aircraft – Rotable History.
- LRU's/ Rotables - Beyond Economic Repair (BER) declarations- Approvals – Replenishment.
- Financials, GL, AR, AP, Financial Statements, Budgeting and Bank Services

Neural networking Extension

IAI has decided to implement IFS Applications (enterprise-wide) with the NN to integrate all functions of a division and bring about better collaboration between the divisions and Central corporate office as a part of Integration of all the Supply Chain Members, by implementing IFS

Applications, aims to standardize, optimize and integrate business processes for Integrated Materials Management, Production Planning and Control, Manufacturing, Quality, Finance, Payroll, Maintenance, Customer Services, Exports, Marketing, Human Resource and Project Management across all divisions/units and customers with Central corporate office with proper authentication keys and protocols.

Conclusion

Inventory is the total amount of goods a business has on hand at a given time. It is a vital asset that keeps that business running smoothly, but too large amounts of inventory can lead to exorbitant cost levels. In Aircraft Servicing industry, Rotables, LRUs and other Bought-Out-Items in substantial quantities must be available to ensure Aircraft Servicing & Maintenance stays on time. This is why IAI implemented various inventory management systems; to control inventory levels to where demand can still be met and costs related to inventory can be minimized. Specifically in the Aircraft Servicing & MRO industry, inventory management is especially important because the costs of the parts being stocked are high.

Furthermore, because costs of the parts are so high requiring large space with special temperature controls and humidity controls, storing inventory requires additional hefty costs. IAI's Servicing Stations have a large infrastructure in place to deal with inventory management. An important facet of IAI's inventory management system is production planning & Rotables Servicing. This involves meeting weekly demand and gauging the requirements under various categories.

Preventing an aircraft-on-ground (AOG) situation is a priority for airlines, as every minute that an aircraft is not flying it loses money & in case of defence aircraft it may be a major threat to the country. Therefore, adopting the most efficient spare parts inventory management and support programme is fundamental to the success of Indian Aircraft Industries. In the aviation business the most critical strategy is to have the right part at the right time, as well as competitiveness apart from profitability. Knowing the demand patterns and planning inventory accordingly is crucial to meet the needs of Aircraft Servicing and Maintenance. In this line the selective inventory control techniques are most useful to increase service levels and to weed-out unwanted inventories.

A system was developed to understand Order risk policy using NN. The advantage of the proposed method is that it can give reorder point using all the information in supply chain regardless of assuming demand pattern especially for LRUs and Rotables for Aircraft Servicing. Computational experiments comparing the order risk policy II with existing policies shows that a significant cost reduction can be obtained by adopting the order risk policy II.

Apart from this, the success of Scientific Inventory Control Techniques and application of combined methods of Inventory Management Techniques has been clearly addressed in this paper. Aircraft Servicing Cycle time reduction along with cost reduction at highest possible service levels in IAI contributed towards the success of each of these pursuits together. Almost 36% cost reduction is seen in Dornier Aircraft servicing with these techniques. Inventory control techniques with figures and facts have been demonstrated to understand the benefits of combination of various Inventory Control techniques in line with the policy patterns of IAI.

However, there is no one optimal solution as to the choice of how costs for aircraft maintenance can be optimized. Still there is lot of scope for additional study in the Area of Inventory Control Systems in Aircraft Industry using innovative Industrial Engineering Systems and applications especially in Aircraft Servicing & Maintenance.

Note: The Figures, Calculations, Views and opinions expressed, conclusions drawn and critical analysis arrived at or any other ideas/ strategies in the above paper are of our own and do not reflect or represent the views of any of the organization

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