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RESEARCH ARTICLE

AN ANALYTICAL STUDY ON THE CONSUMPTION OF SECURITY STICKERS IN AIR CARGO OPERATIONS:

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Abstract

Air cargo operations use security stickers as their most essential yet least examined material resource which they need for their operations. The high-volume express logistics system uses tamper-evident labels to achieve two purposes because they function as main security measures against cargo tampering during all handling procedures while they also fulfil regulatory requirements established by the Directorate General of Civil Aviation (DGCA) and the Bureau of Civil Aviation Security (BCAS). Most cargo stations handle their procurement process and track their daily operations because these two activities remain informal with no established methods to identify their wasteful practices. The research study aimed to investigate the actual security sticker usage pattern, identify the main factors that caused usage differences, and evaluate the current inventory management system maturity for this consumable item. The researchers used direct observation and stock register verification together with standardized questionnaires to gather data from operational staff working in the inbound, outgoing, and security departments. The study establishes that waste levels remain low but human tracking and inconsistent application methods together with unexpected supply chain interruptions create preventable operatio nal inefficiencies.The study presents practical recommendations which enable organizations to move Totowa using digitally monitored RFID s ticker systems together with an inventory system that automatically adjusts during periods of increased cargo demand.

Introduction:-

Air cargo operations today require three essential elements which include speed and operational links and improved delivery capacity. The express logistics hub requires all shipments to undergo three steps which include authentication and sealing and complete documentation in accordance with internal security requirements and external regulatory standards.Security stickers which include tamper-evident seals and VOID labels and holographic identifiers and serialized adhesive tags function as essential physical tools that security personnel use to achieve their objectives. The air cargo industry in India has grown 40 times its previous size during the last 10 years because of increasing e-commerce traffic and pharmaceutical export demands and the fast growth of domestic express

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courier services. The Meenambakkam airport in Chennai functions as the main domestic entrance and operational centre for time-sensitive cargo deliveries throughout India.

The terminal applies security stickers to almost all shipments that go through its processing operations. The organization consumes thousands of commodities each day, yet its operational management of these items does not reach the standards it applies to more valuable assets. Organizations need to buy items after the need arises while tracking systems depend on people to write down information and waste occurs through improper use of adhesives and accidental activation of VOID feature. The terminal applies security stickers to almost all shipments that go through its processing operations. The organization consumes thousands of commodities each day, yet its operational management of these items does not reach the standards it applies to more valuable assets. Organizations need to buy items after the need arises while tracking systems depend on people to write down information and waste occurs through improper use of adhesives and accidental activation of VOID feature. The researchers started their investigation after they found a security sticker usage problem which required them to study how security stickers were used at the airport. The research aims to achieve its goal through two main reasons which include saving costs on frequently needed supplies and protecting cargo security and regulatory compliance through maintaining uninterrupted access to sticker supplies.

Problem Statement:-
Security stickers remain dedicated to use across special cargo areas and departure areas and inbound areas throughout each day. The total cost for high-volume city operations in Chennai becomes significant because every sticker has its own unit cost which appears small. The security sticker shortage which lasts less than a day causes two problems because it prevents cargo movement and endangers BCAS compliance and it damages customer trust. The problem exists because people make assumptions about consumption patterns instead of using proper methods to track it. The process of re-stickering because of adhesive failure and excessive sticker use during peak times and improper sticker waste disposal leads to a gap between actual consumption and required consumption. Security chains become vulnerable to breaches and financial losses occur when this gap remains unaddressed.

Objective if The Study:-
The primary objective of this study is to analyse the consumption pattern of security stickers.

The study specifically aims to achieve the following objectives:
- The study aims to understand security stickers.
- The study wants to measure current sticker usage by tracking all stickers used in main operational areas.
- The study wants to determine which factors lead to different sticker usage patterns by examining shipment type cargo category seasonal demand and operational procedures.
- The study will assess all existing methods used for sticker procurement and storage and inventory reconciliation.
- The study will investigate all instances of excessive consumption and waste and missing items.
- The study will calculate how current consumption patterns affect overall expenses.
- The study will provide recommendations that improve the complete sticker management process based on evaluated evidence.

Scope and Significance of the Study:-
The research investigates only at its Chennai hub which includes three departments that use security stickers for their operations. The researchers collected data through two methods which included a questionnaire-based survey of operational staff and direct observation of handling workflows while using stock registers and usage logs for verification purposes. The study is particularly timely because the air cargo sector in India is experiencing rapid growth and the new regulatory requirements created by this growth. The ICAO and BCAS organizations now require greater cargo security standards which make all consumables that serve as tamper evidence tools more crucial to security operations. The process of understanding consumption drivers and wastage triggers operates beyond cost control functions because it enhances safety and compliance in cargo operations.

Industry Background:-
The air cargo and air freight industry represents the most urgent operational segment of worldwide logistics. The system manages only a small percentage of total trade volume but processes high-value commodities. Air travel is

the only way to get things like pharmaceuticals, semiconductors, perishables, and high-value manufactured goods that can't afford to wait. The global air freight market has experienced significant transformations during the last several years. The COVID-19 pandemic created obstacles for passenger planes to transport cargo, while cross-border e-commerce experienced rapid expansion, and new cargo security regulations emerged.

Global and Indian Scenario:-

Hong Kong, Memphis, Dubai, Frankfurt, and Shanghai are some of the most important hubs in the world that are part of a network that moves hundreds of millions of tons of freight every year. The Asia-Pacific region is now the fastest-growing market, thanks to increased manufacturing in China, India, Vietnam, and Southeast Asia. The IATA says that global air cargo revenue will reach more than $169 billion by 2026, which shows how big the industry is getting. The air cargo industry has grown quickly as India's economy has opened, exports have gone up, and online shopping has become popular. Delhi, Mumbai, Chennai, Bengaluru, and Hyderabad, which are important entry points, have spent a lot of money on new cargo terminals, cold-chain infrastructure, and equipment for security screening. India is one of the biggest exporters of medicines in the world. The pharmaceutical industry depends on air freight to ship medicines that need to be kept at a certain temperature. Because of e-commerce, domestic air cargo has to move faster and ship more often than other industries.

Tamil Nadu and the Chennai Hub:-

Tamil Nadu is a unique entity within the realm of Indian air cargo. It has a wide array of industries that include automobiles, electronics, garments, pharmaceuticals, and marine products. As such, its air cargo comprises a diverse range of goods in high volume. The main air cargo hub for Tamil Nadu is the Chennai International Airport, located in Meenambakkam. With an aircraft fleet comprising Boeing 757-200 and Boeing 737-800 aircraft, the corporation offers services for the transportation of express shipments, time-critical shipments, valuable cargo, and temperature-controlled goods on behalf of their customers from all sorts of industries. The size of operations at this hub ensures that operational supplies, including security labels, are used up quickly.

Review of Literature:-

Air cargo security studies have seen significant development in recent times. This research work can rely on many lines of research which are relevant to the subject area. A comparison of the effects of extended cargo inspection was performed by Nowakowski &Ryczyński (2025) on two cargo facilities in southern Poland and southern Europe from 2022 through 2024. Their study highlighted a significant difference in inspection delays at the latter site, which had average additional delay times of 84-95 hours due to rerouting of the shipment to extended cargo inspection. The primary suggestion made by Nowakowski &Ryczyński was that the availability of on-call personnel along with automatic triggers to the planning team in response to negative results on X-ray inspection would decrease consumption of physical security resources.

Jurgelāne-Kaldava (2025), in her article "Digitalization of the Air Cargo Supply Chain in Latvia," claims that fragmentary data integration is the biggest barrier to improving the supply chain process. According to her suggestions, IATA ONE Record can be used to construct an integrated digital-tracking system. She also stresses the importance of IoT in maintaining Known Consignor status. This information is useful in further research regarding digital-tracing systems for consumable products such as security stickers. Antonic (2022) designed the Smart Sticker gadget for shock detection in logistics at ultra-low power levels. This technology shows how adhesive sensors can work in three different ways – low-power sensing mode, active logging, and NFC-enabled data transmission – yet still preserve enough battery energy for long-distance travel. Even though this research project does not deal with product tampering but instead is concerned with identifying any damages to products within logistics networks, it clearly shows how traditional security stickers can be developed into advanced sensors.

Tampering evidence was explored by Wong (2026) in the context of aviation catering and cargo logistics, emphasizing that the main significance of VOID stickers is not only about their deterrent effect but also about the evidence that can be generated from such stickers. Airlines and ground handling agencies can easily track any incident of tampering back to a particular handler, his shift, and his time slot if the sticker number is tied with the cargo manifest and handler’s shift schedule. The authors Jodejko-Pietruczuk& Tubis (2025) tested Augmented Reality systems' efficiency in terms of hazardous goods acceptance in airport cargo warehouse terminals. The results demonstrated that AR goggles helped to improve operators' performance in terms of documentation checking. However, interaction-oriented Augmented Reality capabilities were perceived negatively by the operators. This study highlights a more general idea, which states that technology may significantly help ground service personnel

in their difficult work related to strict regulations. Therefore, the above hypothesis seems to be correct. According to Dataintelo (2024), a global forecast of the air cargo security screening market expected to be worth around $1.65 billion in 2024 would grow at a CAGR of 6.8% to reach a value of $3.03 billion by 2033. One of the driving factors mentioned includes shifting from manual checks to AI-based CT and X-ray screening with North America and Europe being early adopters while the Asia-Pacific region records fast growth. The observation made by the report on human skill gaps in the application of new technology is very relevant since with enhanced physical security, the weakest point is the person applying/inspecting the tamper seal.

The design development of adhesive-free security stickers which protect airplane surfaces from adhesive damage was documented by American Casting and Manufacturing in their 2025 report. The study focused on the fact that aviation tamper-evident stickers must withstand such severe conditions as low and high temperatures, UV radiation, fast decompression, and abrasion, all of which standard commercial stickers cannot endure. The necessity of aviation stickers becomes clear through this situation. The study draws on Persistence Market Research (2025)'s theory about security gaps, wherein highly funded international airports with capabilities to utilize CT scanning for explosive detection and smart labelling technologies are compared to regional airports that use basic physical methods. Blue Dart Aviation's Chennai terminal falls in between, as it has more resources than typical local airports but is not at the edge of full digitalization. This knowledge sets the stage for understanding the study's findings.
Towards Packaging Organisation (2025) found out that 71% of consumers currently make considerations about the safety and sustainability aspects of products prior to purchasing them, thereby creating the need for labels that have both tampering prevention capabilities and provide transparency within the supply chain using Near Field Communication and Quick Response labels. Blockchain-based label verification is increasingly becoming a common practice in North America, while Asia-Pacific regions are registering the highest growth rates worldwide. Implications on air cargo operations are clear, considering that consumers are now more knowledgeable about safety.

Research Gap:-
In addition, there is a lack of systematic modelling to establish the relationship between seasonal surges in shipping and consumption demands for security stickers. Unlike relying on quantitative modellingmethods such as Economic Order Quantity or forecasting the demand from time series data, security sticker stock control in many Indian cargo facilities is more intuitive., there is no research conducted in the Indian air cargo logistics industry regarding the human factors associated with the process of security sticker application, especially the impact of reduced ground handling time, inadequate training, and design flaws of the stickers causing improper application. The current study hopes to help fill this gap through the analysis of the actual operational experience at the Indian express air cargo hub.

Research Methodology:-
The study adopted the descriptive-analytical approach. In the descriptive aspect, the focus is on mapping the existing trend of security sticker usage, in terms of flow and amount, among the various operating divisions. In the analytical side, the objective is to determine the reasons behind the variations – that is, what kind of cargo, period, and operating environment results to high/low consumption rate.

Research Design:-
The study title is: "An Analytical Study on the Consumption of Security Stickers at Blue Dart Aviation." The study investigates whether security sticker usage at the Chennai hub actual usage matches established standards. The existence of this gap will become evident through three specific outcomes which include over-consumption of stickers beyond their necessary operational requirements and wastage through sticker damage and misapplication and through stock-out risk which occurs when inventory levels fail to meet maximum demand periods.

Data Collection:-
The research team collected primary data by distributing a structured questionnaire to all staff members who worked in inbound, outbound, security, and operations departments at the Chennai hub. The 27-item questionnaire included sections that assessed the respondent's background information and their shipment volume operations together with their sticker usage patterns and their cargo handling methods and their seasonal consumption practices and their inventory management systems and their waste assessment methods and their training history and their overall contentment with the current sticker management system. The research team conducted direct observations at Unit Load Device packing areas to check whether survey results matched actual equipment handling procedures.

Secondary data were drawn from internal stock registers and inventory records and cargo manifests which enabled the matching of shipment volumes to sticker issuance and from published regulatory and market research reports.

Sampling:-
The Chennai hub operates 17 different cargo types which include international and domestic airfreight along with general packages and high-value goods and pharmaceutical shipments and e-commerce returns. The study used a stratified sampling method to select samples from the study population because the researchers wanted to include all essential cargo types and department types in their research. The researchers used 12 to 24 months of records to obtain longitudinal consumption data which enabled them to track seasonal patterns that included major festive periods.

Data Analysis Tools:-
Researchers assessed security sticker criticality through ABC-VED matrix analysis which determined that essential stickers for BCAS regulatory compliance required complete availability while cargo container tamper-evident seals received Essential status and all other security labels received Desirable status. The actual sticker issuance records were compared to the theoretical sticker requirements which were based on shipment counts and standard stickers-per-shipment benchmarks to identify unexplainable sticker consumption. We obtained optimal procurement quantity estimations through Economic Order Quantity calculations which used data we collected from our research. The research used trend analysis to track sticker consumption growth which it compared against cargo tonnage growth in order to determine whether sticker usage matched operational scale.

Data Analysis and Interpretation:-
The upcoming section displays the analysis results which were obtained through primary data collected from Blue Dart Aviation operational staff in Chennai. The survey results are presented in each table which shows the responses and it includes an analysis of the results that relates to the operational activities at the hub.

Usage of Security Stickers (Table 1)

Response	Count	Percentage
Yes	9	90%
No	1	10%
Total	10	100%

Security stickers constitute an essential part of daily activities according to 90% of respondents who participated in the study. The business operates with physical seals and documentation-based security methods while the business uses these two security methods. Stickers function as essential materials for operations because their usage extends to all operational activities of the organization. The hub experiences operational disruptions because any stoppage in sticker supply affects all operational areas.

Shipments Processed per Shift (Table 2):-

Volume Range	Count	Percentage
50–100 shipments	2	20%
101–200 shipments	3	30%
Above 200 shipments	5	50%

The Chennai hub operates as a high-throughput facility because the majority of staff members handle more than 200 shipments during each work period. Sticker consumption is directly impacted by this volume intensity: over the course of a month's operation, even minor inefficiencies in per-shipment usage, such as an extra sticker applied needlessly or a sticker peeled and thrown due to positioning error, can add up to significant waste. The procurement planning process will result in excessive stock purchasing when sticker demand is treated as a constant time-based requirement and will also lead to stock shortages because of this incorrect demand estimation method.

Stickers Used per Shipment (Table 3)

Stickers per Shipment	Count	Percentage
2–3 stickers	2	20%
4–6 stickers	3	30%
More than 6 stickers	5	50%

Most handlers use more than six stickers when they handle one shipment package according to the data. The standard requires security measures to be implemented through three different security points which include ULD assembly and consignment sealing and regulatory labeling. The study indicates that specific shipment types especially those containing high-value items and multiple packaged goods need additional material for each unit than the standard average material requirement. The inventory models that calculate demand for complex cargo categories through a basic per-shipment average method will consistently deliver inaccurate results.

Cargo Category with Highest Sticker Consumption (Table 4):-

Cargo Category	Count	Percentage
High-Value / Electronics	4	40%
E-commerce Shipments	3	30%
Pharmaceutical / Vulnerable Cargo	2	20%
Others	1	10%

The primary driver of sticker usage which takes up 40% of total capacity needs to meet security requirements which apply to high-value goods and electronic products. The segment requires 30% of resources because e-commerce returns and forward parcels need multiple handling steps before they reach their destination. Pharmaceutical cargo with 20% of total volume requires the highest level of regulatory control because any signs of tampering with medicine shipments must undergo complete examination according to aviation safety regulations.

Peak Consumption Period (Table 5):-

Period	Count	Percentage
Festive / Holiday Season	4	40%
Month-End Business Cycle	3	30%
Consistent Throughout Year	3	30%

The biggest increases in consumption (40%) occur during holidays like Diwali, Pongal, Christmas, and significant e-commerce sales. The current procurement process does not create buffer stock to handle predictable events despite their ability to forecast upcoming situations. A second recurring consumption peak is added by month-end spikes, which are probably caused by batch shipment deliveries and billing cycle completion. The organization needs a demand-based procurement calendar because the current system depends on reactive inventory restoration.

Stock-Out Frequency (Table 6)

Frequency	Count	Percentage
Never experienced stock-out	5	50%
Rarely (once a year)	4	40%
Occasionally (every few months)	1	10%

While 50% of respondents report having never encountered a sticker stock-out, the remaining 50% have experienced at least one instance of zero inventory during the survey period. A stock-out in aviation security situations creates

more than just operational difficulties because it leads to shipment delays and results in BCAS sealing requirement violations. The 40% who report rare but recurring stock-outs suggest that the current replenishment system lacks sufficient buffer stock to absorb demand spikes without interruption.

Estimated Sticker Wastage (Table 7):-

Wastage Level	Count	Percentage
Less than 2%	6	60%
2%–5%	3	30%
Above 5%	1	10%

The initial impression of the waste statistics which show 60% of operations maintaining waste levels below 2% looks positive. The hub which handles 200000 stickers per month shows substantial material loss together with its associated costs because it maintains a waste rate between 2% and 5%. The 10% of respondents who reported waste levels beyond 5% require special investigation because this threshold indicates a particular operational breakdown which needs examination of adhesive quality problems and storage humidity conditions and training deficiencies.

Current Inventory Tracking Method (Table 8):-

Tracking Method	Count	Percentage
Digital / ERP-based system	5	50%
Manual logbook	3	30%
No formal tracking	2	20%

The hub experiences operational challenges because 50 percent of its sticker inventory remains untracked through manual methods and 20 percent of its inventory exists without any tracking mechanism.

Primary Reason for Re-Stickering (Table 9)

Reason	Count	Percentage
Damage during handling	5	50%
Secondary security re-check required	3	30%
Other reasons	2	20%

The sticker application process and the physical conditions under which branded freight is subsequently handled are the primary cause of unanticipated additional consumption, as handling-related damage accounts for 50 percent of re-stickering costs. The handlings conditions at this specific hub will cause re-stickering rates to remain high because the sticker physical properties need to meet two requirements.

Time Required for Sticker Application (Table 10):-

Time to Apply	Count	Percentage
Less than 30 seconds	4	40%
30–60 seconds	3	30%
1–2 minutes	3	30%

The variation in application times over three district ranges is indicative of the absence of a standard operating procedure for sticker application. The fact that some handlers finish their work within 30 seconds while others take two minutes demonstrates that they use different methods and handle cargo with different abilities. The implementation of standardized application procedures together with surface preparation methods and placement

position specifications and required adhesion pressure will lead to decreased re-stickering rates and application errors.

Training Received on Sticker Application (Table 11):-

Training Type	Count	Percentage
Informal / On-the-job learning	6	60%
Formal induction or refresher training	4	40%

The high usage of informal work-based training which is used by 60% of employees creates direct effects on operational activities. The learning process for experienced workers involves two distinct paths because they acquire both effective personal techniques and forbidden shortcuts which include incorrect methods that violate best practices. The lack of structured training programs forces new employees to depend on their coworkers instead of following established procedures which results in the reinforcement of existing harmful work practices.

Openness to Smart Sticker Technology (Table 12):-

Response	Count	Percentage
Yes, it is necessary	6	60%
It might help but seems expensive	3	30%
Current system is sufficient	1	10%

The high usage of informal work-based training which is used by 60% of employees creates direct effects on operational activities. The learning process for experienced workers involves two distinct paths because they acquire both effective personal techniques and forbidden shortcuts which include incorrect methods that violate best practices. The lack of structured training programs forces new employees to depend on their coworkers instead of following established procedures which results in the reinforcement of existing harmful work practices.

Identified Bottlenecks in Sticker Management (Table 13):-

Bottleneck	Count	Percentage
Vendor supply delays	4	40%
Lack of automated tracking	3	30%
Sticker quality issues	2	20%
Other factors	1	10%

The operational process reaches its maximum limit because vendor reliability acts as its main constraint which impacts 40 percent of operational activities. The need for strategic inventory management emerges because safety stock needs to cover 15to30 days of operations after reaching the standard reorder point. The company needs to develop its upstream supply chain and internal monitoring system because tracking gaps and quality problems show a need for improvement.

Overall Satisfaction with Sticker Management System (Table 14):-

Satisfaction Level	Count	Percentage
Very Good	3	30%
Good	6	60%
Neutral or below	1	10%

The results show high satisfaction with 90% of respondents rating their experience as either good or very good yet these results need careful assessment. The employee happiness level in the workplace demonstrates that 50% of employees have experienced stock-outs while 50% use manual tracking methods which results in operational

inefficiencies that employees accept because they know how to use the system. Operational staff satisfaction data in high-routine situations does not measure system performance because it only shows how familiar staff members are with their tasks.

Key Findings:-

The following are the main conclusions drawn from the examination of survey data, observation records, and secondary inventory information. Security stickers serve as vital components for both cargo security and legal compliance requirements, which all operational departments use throughout their work. The operational importance of these items causes them to be categorized as vital items in the ABC-VED matrix which requires organizations to maintain continuous stock availability of these products. The high-throughput environment that handles over 200 shipments daily from complex shipments needs two or more stickers for each shipment to operate efficiently. The hub currently experiences its highest usage through electronics and e-commerce and pharmaceutical cargo categories. The current procurement procedures fail to establish pre-built inventory stockpiles for the upcoming holiday periods despite their predictable nature and their occurrence during seasonal demand spikes. The hub experiences supply chain disruptions because it operates at full capacity during peak times.

Inventory monitoring is still not fully digitalized, with 20% of sticker management done through no formal system at all and 50% done through manual record keeping. This result in visibility gaps that hinder proactive stock management and make it challenging to spot waste or unlawful use. The total waste generated becomes a major expense because it reaches beyond 50% of total consumption. The main problem which leads to unneeded extra usage needs to be addressed through two main points: physical handling process and sticker material specifications.The majority of employee sticker application training is informal. Adhesive failures, unintentional The current implementation of the approach leads to two specific problems which include VOID triggering and re-sticker incidents. The most important external element which affects supply continuity depends on vendor reliability while the workforce shows positive attitudes toward adopting RFID and smart tag system technologies.

Recommendations:-

The following suggestions are made to enhance the management of security sticker consumption considering the results listed above:

1. Put ERP-Integrated Digital Tracking into practice
2. Create a Procurement calendar based on demand
3. Test Smart Sticker or RFID Technology
4. Standardize formal training and Application procedure
5. Perform routine audits of reconciliation
6. Boost diversification and Vendor management
7. Create a monitoring dashboard.

Conclusion:-

Security stickers need to be handled through automated systems instead of their current manual operational method which functions as a temporary solution. The hub can replace experience-based monitoring with standardized digital records by moving to a data-driven approach that makes use of RFID and ERP connections. The operation transforms from an adequate state into a high-integrity system through its ability to eliminate stock-out, reduce waste, and achieve complete regulatory compliance which improves customer trust in every secured shipment.

Appendix:-

1. The research used an Appendix A which included a structured questionnaire that contained 27 items to evaluate the operational staff of Blue Dart Aviation in Chennai. The complete questionnaire can be accessed through the following link httpsdocsgooglecomforms.
2. Appendix B: Table of Contents for Data Collection from the Lab. Retrieved at: https://docs.google.com/spreadsheets/ with Critical ingredients of single elements on a single row identifiable at 1 item stage of selection, with appropriate categorization.
3. Appendix C with charts and graphical illustrations for all 22 data tables displayed in the analysis section.
4. There are regulatory references in Appendix D – DGCA (https://www.dgca.gov.in), ICAO (https://www.icao.int), BCAS guidelines on cargo security sealing requirements.

5. Appendix E: Source of information in respect of the company website and its authentic documents; Blue Dart Express Limited (https://www.bluedart.com).

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