IMPROVING LOGISTICAL OPERATIONAL READINESS - Allocation of Equipment during Major Planned Events

NUS National University of Singapore

DEPARTMENT OF INDUSTRIAL & SYSTEMS ENGINEERING | IE3100R SYSTEMS DESIGN PROJECT

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ABSTRACT: This project aims to improve the capability of the Singapore Police Force (SPF) in managing their logistical system to support major planned events such as F1 and NDP. It is scoped into 3 main components, each dealing with a different aspect of fulfilling the logistical requirements of major planned events. These solutions were then developed into Excel VBA Tools for deployment in SPF. The team liaised directly with key members of the police force to develop these solutions.

PROBLEM DEFINITION

PROJECT OBJECTIVE: To conduct research on SPF's existing equipment deployment strategy and distribution model by:

1) Analysing the strengths and weaknesses of existing deployment strategy and distribution model
2) Developing improved models to enhance logistics readiness and optimize logistics deployment
3) Proposing recommendations to achieve optimal readiness for major planned events

1 CLASSIFICATION OF LOGISTICS ITEMS

- Derive an objective classification of logistics items for inventory management
- Determine items that are more crucial for operational success and hence require a higher priority for storage

Based on the item's classifications...

2 STATISTICAL ANALYSIS OF LOGISTICS INVENTORY LEVELS

- Ensure inventory levels are sufficient to meet major planned event needs
- Determine inventory performance measures and target inventory levels to enhance logistics readiness

... Identify suitable inventory management strategies ...

3 OPTIMIZATION OF LOGISTICS DEPLOYMENT PLAN

- Ensure efficient logistics deployment to on-the-ground officers during major planned events' emergencies
- Determine the strategic placement of Forward Logistics Base (FLB) at major planned event site

... Operate efficiently with logistics inventory.

ANALYSIS & RECOMMENDATIONS

LOGISTICS ITEMS

AIM: Provide a more objective measure of criticality by translating the experience of assessing it into an index that comprehensively considers all evaluation criteria, and propose an improved criticality classification methodology.

BEFORE

Only 2 categories in determining the critically of an item by the Key Management

- CRITICAL
- ESSENTIAL

AFTER: CRITICALITY INDEX

Factors → Rubric-based Scoring → Calculations → Composite Score

- Operational Impact
- Likelihood of Usage
- Operational Efficiency
- Mitigating Item Shortage

Criteria	Score 1 – 2	3 – 4	5 – 6	7 – 8
Operational Impact	No damage to property. Public safety not affected.	Possible damage to property. Public safety minimally affected.	Damage to property. Public safety somewhat compromised.	Severe damage to property. Severely compromise public safety.
Operational Efficiency	Event able to proceed as planned with minor inconveniences. No effect on public order.	Event able to proceed with some operational plan modifications. Minimal effect on public order.	Event able to proceed with significant operational plan modifications. Public order somewhat compromised.	Event unable to proceed. Severely compromise public order.
Likelihood of Usage	Rarely used during event.	Occasional usage during event.	Frequent usage during event.	Consistent usage during event.
Ease of mitigating item shortage	Easily substitutable with other items. Procurement time of less than 1 week.	Substitutable with other items. Procurement time of 1 week – 1 month.	Poorly substituted with other items. Procurement time of 2 – 5 months.	Not substitutable with other items. Procurement time of 6 months and above.

Standardization
Weighting
Aggregation

Increasing Level of Criticality

- LEVEL 1
- LEVEL 2
- LEVEL 3

LOGISTICS INVENTORY LEVELS

AIM: Right-size inventory level of logistics held by SPF to ensure the operational success of major planned events.

PROBLEM DESCRIPTION:

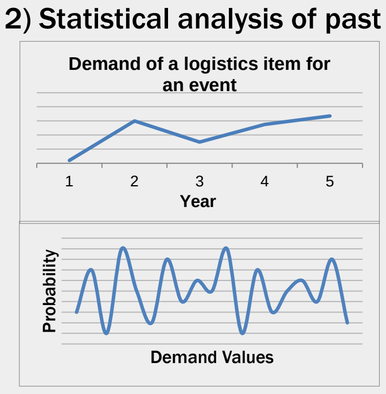
- Inventory amounts are determined heuristically based on experience → Give a guide to how much inventory to hold, based on statistical calculations
- Some items face shortage during major events while others were stored in excess
- Dispersed data across multiple files makes it difficult to perform holistic analysis → Consolidate demand data of numerous events and years to facilitate analysis

SOLUTION APPROACH:

1) Research on Key Performance Indicators (KPIs) used in the industry to evaluate inventory performance:

Alpha (α) Service Level	Beta (β) Service Level
Fulfillment Probability	Utilisation
Probability that demand for an event can be satisfied with inventory on hand	Percentage of current inventory used to fulfill demand for an event

2) Statistical analysis of past logistics items' demand data:



Challenges
× Unable to determine distribution due to limited data points
× No observable trend
× High variation makes it even more difficult to obtain a meaningfully confident estimate on the prediction of future requirements

3) Application of *Cantelli's Inequality* to determine worst case KPI values regardless of underlying distribution:

$$Cantelli's\ Inequality: \Pr(X \geq \mu + k\sigma) \leq \frac{\sigma^2}{\sigma^2 + (k\sigma)^2} = (1 - \alpha)$$

μ (Mean); σ (Standard Deviation) from Demand Data

$$\text{Fulfillment Rate} = \alpha = \Pr(\mu \leq Current\ Inventory) = \frac{k^2}{1+k^2}, \text{ where } k = \frac{Current\ Inventory - \mu}{\sigma}$$

$$\text{Utilization} = {}^{1}/_{\beta} = \frac{\mu}{Current\ Inventory}$$

TOOL DEVELOPMENT:

4) Develop methodology to decide on KPI target values:

Criticality Index	Target Fulfillment Probability, α %	
	Lower Bound	Upper Bound
Level 1	85%	99%
Level 2	90%	99%
Level 3	95%	99%

5) Suggest the range of optimal inventory amounts for each item. The lower bound is given by the highest value of minimum inventory required across all events. The upper bound is given by the highest value of maximum inventory required across all events.

$$\text{Suggested Inventory Level} = \mu + k\sigma, \text{where } k = \sqrt{\frac{\alpha}{1-\alpha}}$$

KEY BENEFITS & OUTPUTS:

- Focuses on usability
- Excel based tool with VBA
- Easy to obtain inputs
- Automates complex calculations
- Built-in error handling
- Easy to understand outputs

Tool

Model Outputs
Summary statistics for each event
Current inventory performance based on consolidated data
Suggested inventory level for each item
Various charts & graphs for data analysis

OUTCOME ANALYSIS: Current Inventory Performance was evaluated. Inventory items were identified according to:

Shortage	36.8%	Mostly consumable items that can be easily procured as their short purchasing lead time allows them to be bought just before the event and hence need not be stored
Healthy	26.3%	Mostly items which are specifically used for major planned events, thus they do not experience high variations in demand
Excess	36.9%	Typically items which are heavily utilized for daily operations and/or difficult to procure, hence necessitating a higher level of inventory to hold

LOGISTICS DEPLOYMENT PLAN

AIM: Determine the most optimal locations to place FLBs to ensure highest efficiency and effectiveness of distribution of logistical equipment.

PROBLEM DESCRIPTION:

Legend –
n : *Possible FLB Locations* (Available for use & sufficient space capacity
⊗ : *Critical Point (CP) Locations* (Used for security screenings, rest areas, key infrastructures)

Response Time – Time taken to move logistics from a FLB to a critical point

Distribution Methods for logistics during emergency –

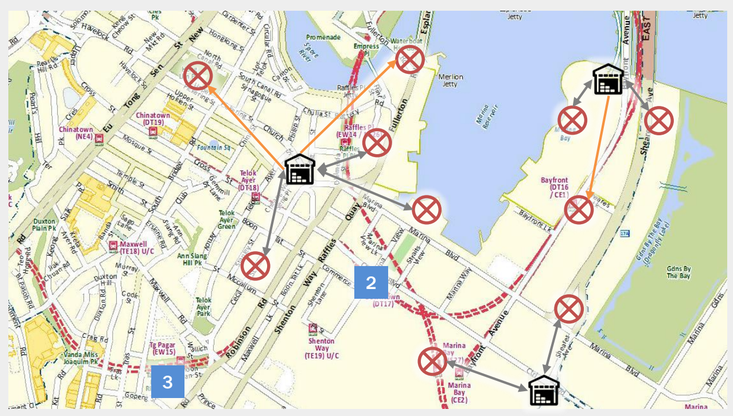
PULL: Officer at CP ⇄ FLB — OR — PUSH: Officer at FLB → Officer at CP

SOLUTION APPROACH: Design an optimization model to determine most optimal logistics deployment plan.

Objective Function	▪ Minimize: Average Response Time to CPs
Decision Variables	▪ Where to build FLBs? ▪ Which FLB serves which CP's logistical needs? ▪ Which CPs to adopt PUSH Distribution?
Constraints	▪ Max acceptable response time ▪ Max no. of FLBs built and CPs pushed

TOOL DEVELOPMENT: Built an Excel VBA tool for optimization with input flexibility to enable it to be applied for any event of any terrain and scale.

OUTCOME ANALYSIS: Logistics deployment could be planned using a more structured scientific framework, and efficiency of it could be determined from KPIs (minimum, maximum and average response time) derived from model outputs.



Legend –
: FLB Locations Built
→ : PUSH Distribution Method ⇄ : PULL Distribution Method

Model was verified and validated based on past logistics deployment data.

Tool was tested and used by PLD during a Table-Top Exercise for the preliminary logistics deployment planning of an upcoming major event.