Advancing U.S. Marine Corps Warehouse Management Operations Through System Architecture and Analysis

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Background

- A critical enabler of military superiority is operational availability
  - The probability warfighting systems will be functional when called upon
- A critical enabler of operational availability is delivering parts where and when needed in order to reduce downtime
- A critical enabler of reduced downtime is staging parts close to their demand
- Therefore, the need for warehouses (storing for future demand)

This presentation is not about hardware or software functionality…

it is about architectural behavior

Agenda

- System Overview
- Fault Tree Analysis
- Monte Carlo Analysis
- Findings and Conclusions

System Overview

Increasing complexity (functions, data, and responsiveness)

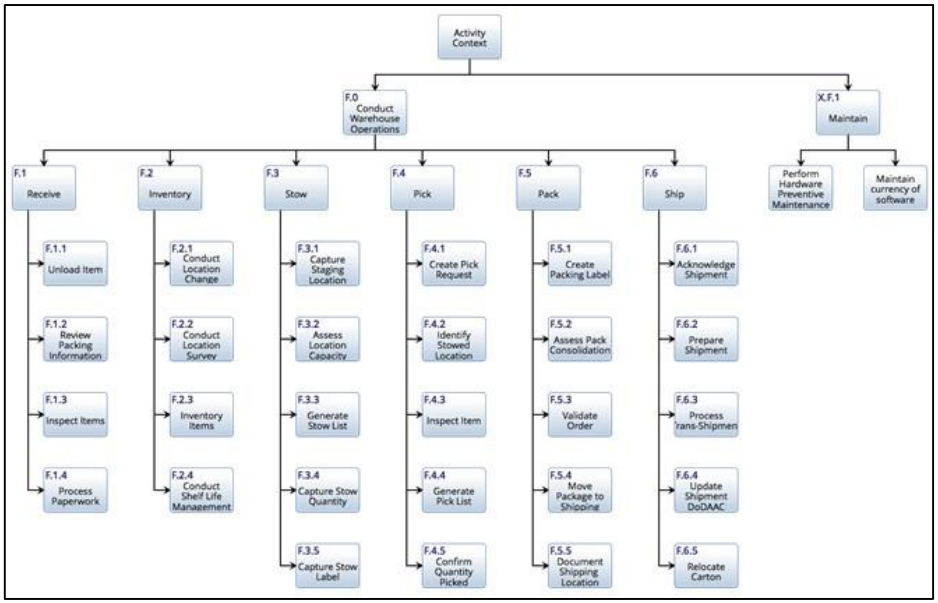
Kitchen Pantry

USMC Warehouse

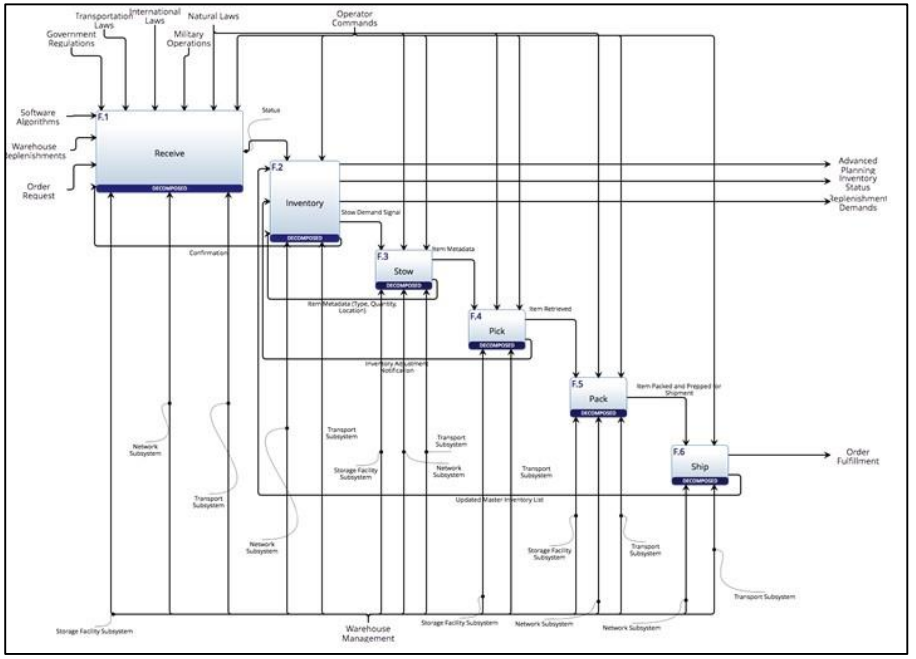
Amazon Distribution Center

- **Globally pre-positioned permanent and temporary locations for storage of items to satisfy military demands and high operational availability**
  - Supply Maintenance Units (SMU)
  - Repairable Issue Points (RIP)
  - Using Units (UU)
  - Initial Issue Provisioning (IIP)
- **Warehouse capability accounts for item:**
  - Volume
  - Weight
  - HAZMAT category
  - Incompatibility with other materials
  - Shelf life

System Overview



Activity Context

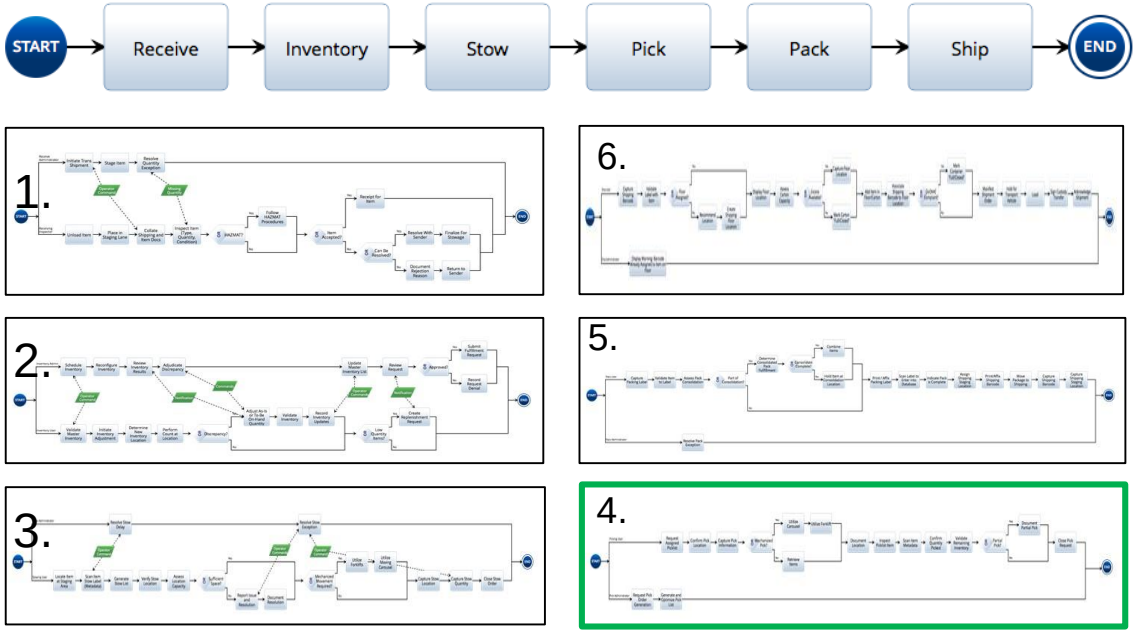


IDEF0 Diagram

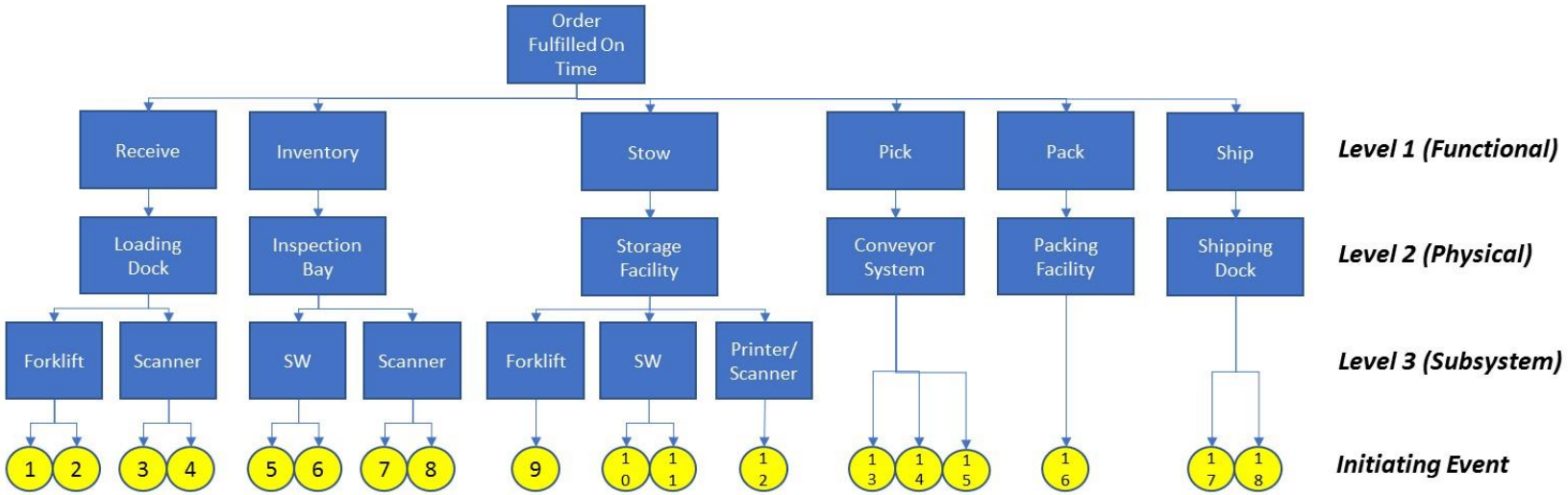
Warehouse Process Analysis

Operational View

System Top Level Functions



Master Logic Diagram (Identify Initiating Events)

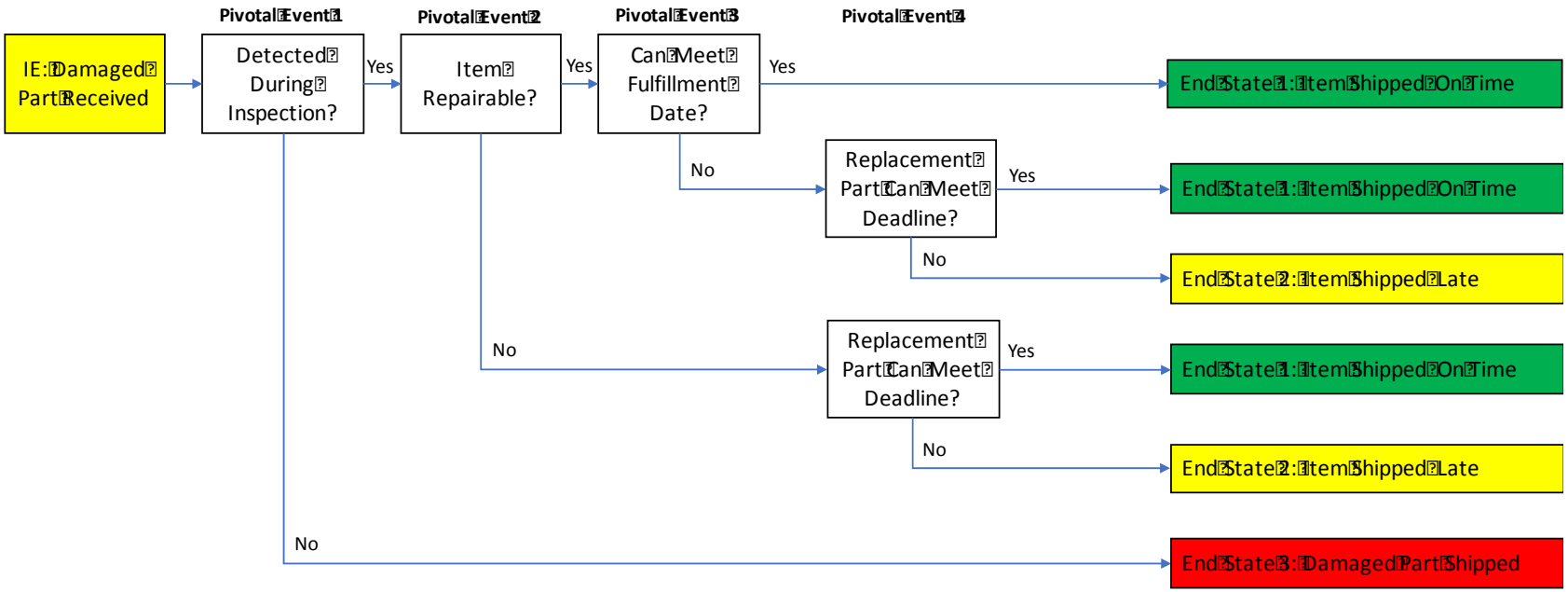


1. **Damage to Item**
2. Incorrectly Placed
3. Malfunction
4. Incorrect Item Scanned
5. Incorrect Information Entered
6. Incorrect Shelf Life Entered
7. Malfunction
8. Faulty Data Entry
9. Faulty Equipment (Damage to Item)

10. **Loss of Network Connectivity**
11. Incorrect Inventory Record
12. Incorrectly Labeled
13. Incorrectly Placed (Stowed)
14. **Inadequate Inventory**
15. Incorrectly Picked Item
16. Incorrect Quantity Picked
17. Wrong Truck Loaded
18. Labels Not Verified

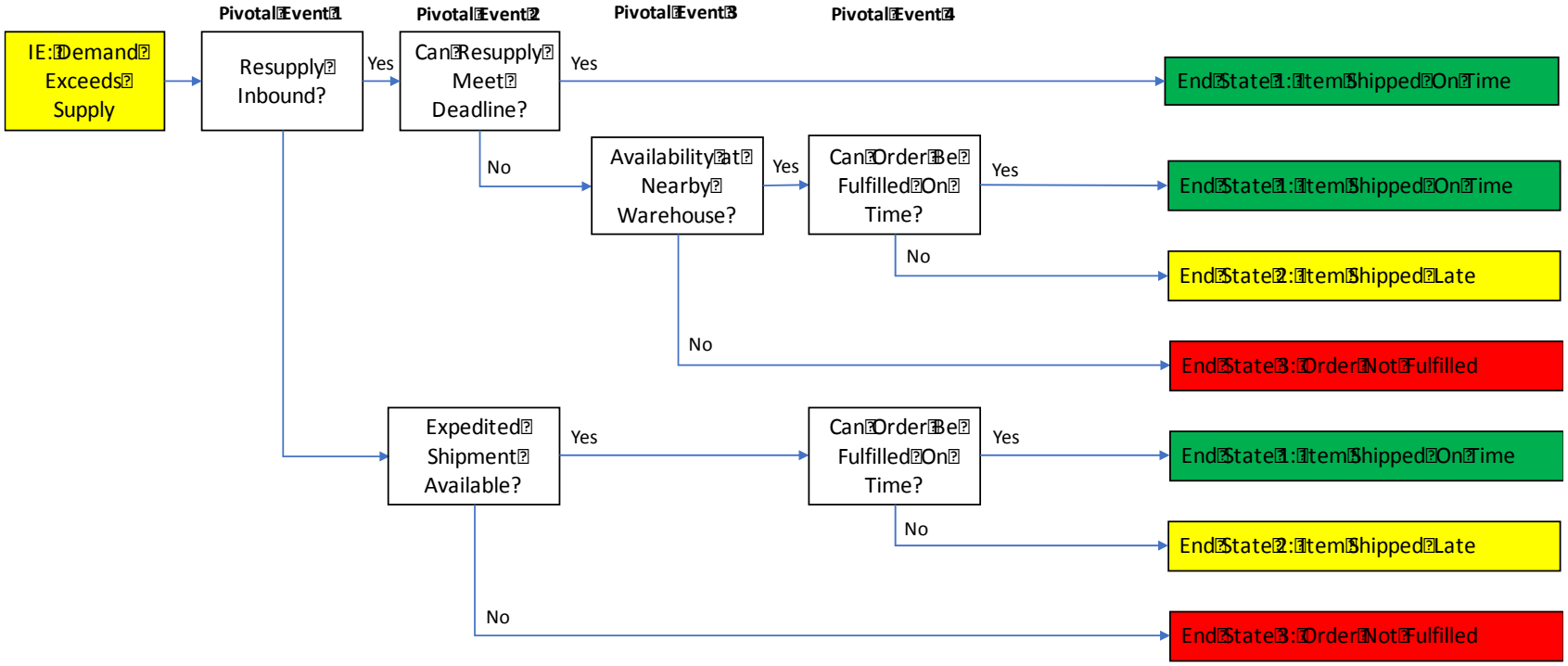
* Reference: NASA/SP-2011-3421, 2nd Ed. 2011.

Event Tree (IE1: Damaged Part Received)



* Reference: NASA/SP-2011-3421, 2nd Ed. 2011.

Event Tree (IE2: Demand Exceeds Supply)



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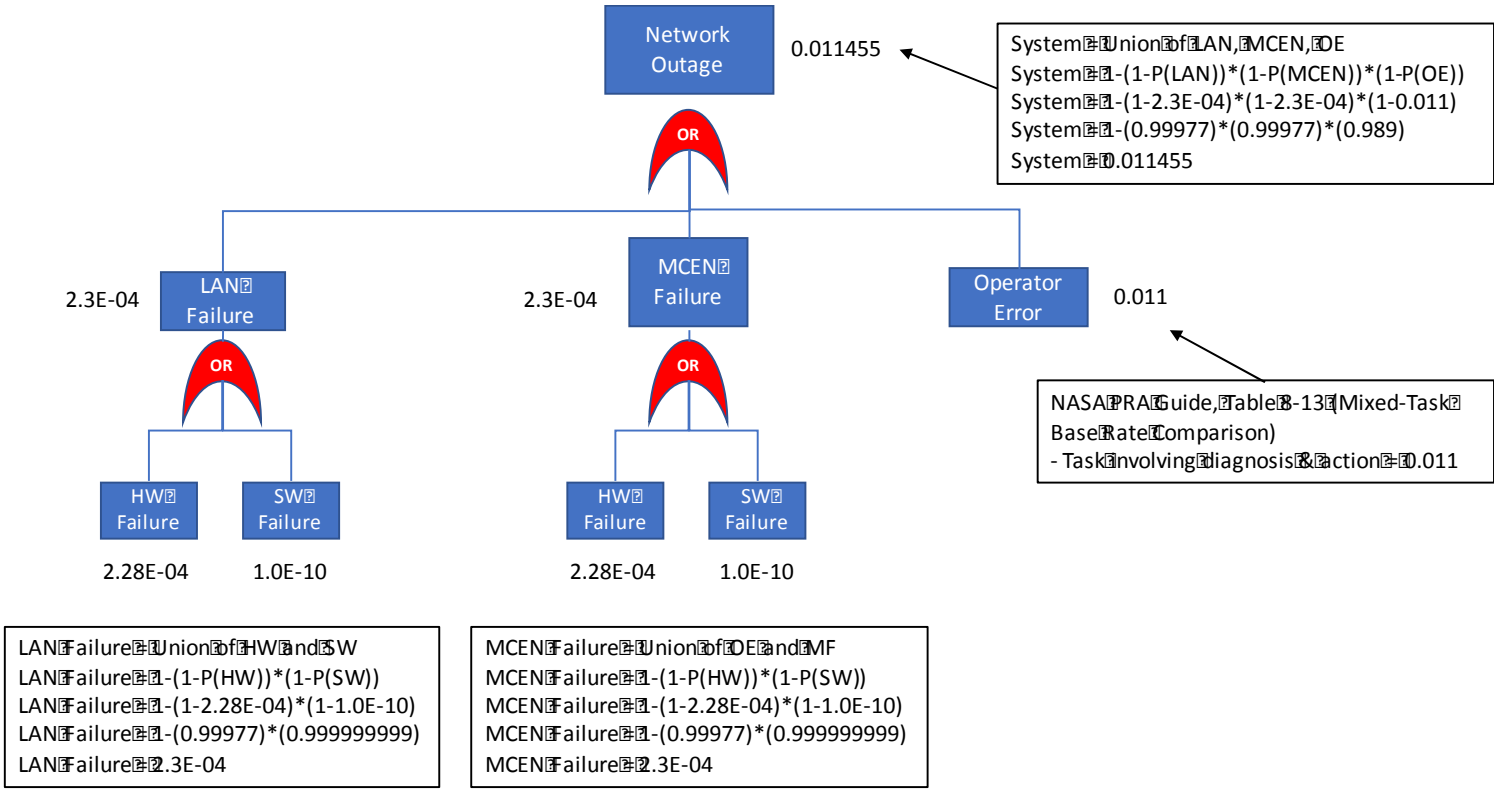
Fault Tree Analysis



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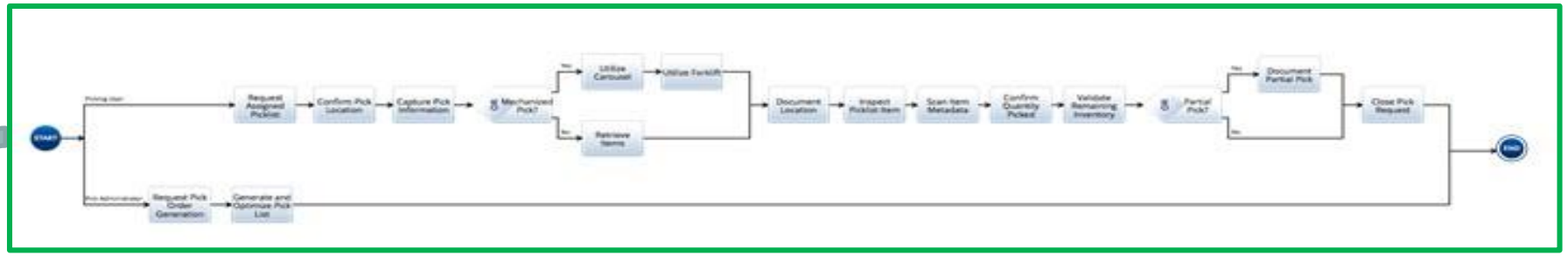
Schedule Analysis Inputs (Pick Sub Process)



Task #	Title	Basic Duration (min)	Best Case	Most Likely	Worst Case	Risk Factor	Distribution
1	Request Pick Order	0.2	0.2	0.208	0.22	L	Triangular
2	Generate Pick Order	0.2	0.2	0.218	0.248	M	Triangular
3	Request Assigned Picklist	0.2	0.2	0.212	0.23	L+	Triangular
4	Confirm Pick Location	1	1	1.04	1.1	L	Triangular
5	Capture Pick Information	1	1	1.04	1.1	L	Triangular
6	Utilize Carousel	5	5	5.3	5.75	L+	Triangular
7	Utilize Forklift	10	10	12	15.5	H	Triangular
8	Retrieve Items	5	5	5.3	5.75	L+	Triangular
9	Document Location	1	1	1.04	1.1	L	Triangular
10	Inspect Packlist Item	2	2	2.12	2.3	L+	Triangular
11	Scan Item Metadata	0.2	0.2	0.208	0.22	L	Triangular
12	Confirm Quantity Picked	1	1	1.04	1.1	L	Triangular
13	Validate Remaining Inventory	3	3	3.12	3.3	L	Triangular
14	Document Partial Pick	2	2	2.08	2.2	L	Triangular
15	Close Request	0.2	0.2	0.208	0.22	L	Triangular

Path #1	Duration
1	0.200
2	0.200
3	0.200
4	1.000
5	1.000
6	5.000
7	10.000
9	1.000
10	2.000
11	0.200
12	1.000
13	3.000
14	2.000
15	0.200
Total Path #1	27.000
P1 CR path?	1

Path #2	Duration
1	0.200
2	0.200
3	0.200
4	1.000
5	1.000
8	5.000
9	1.000
10	2.000
11	0.200
12	1.000
13	3.000
15	0.200
Total Path #2	15.000
P2 CR path?	0

Path #3	Duration
1	0.200
2	0.200
3	0.200
4	1.000
5	1.000
8	5.000
9	1.000
10	2.000
11	0.200
12	1.000
13	3.000
14	2.000
15	0.200
Total Path #3	17.000
P3 CR path?	0

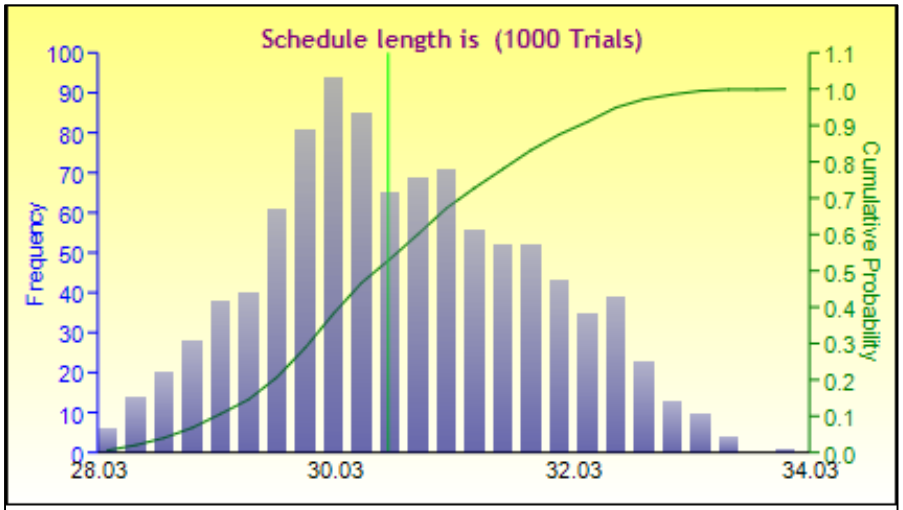
Path #4	Duration
1	0.200
2	0.200
3	0.200
4	1.000
5	1.000
6	5.000
7	10.000
9	1.000
10	2.000
11	0.200
12	1.000
13	3.000
15	0.200
Total Path #4	25.000
P4 CR path?	0

Schedule length is 27.000

How Long Should It Take From Order Fulfillment Request To Prepping For Shipment?

* Reference: NASA/SP-2011-3421, 2nd Ed. 2011.

Schedule Analysis (Pick Sub-Process)



Type: Two-Tail, Lower: -Infinity, Upper: Infinity, Certainty: 100.0000%

Number of Trials	1000
Mean	**30.4831**
Median	30.3745
Standard Deviation	**1.1349**
Variance	1.2880
Coefficient of Variation	0.0372
Maximum	33.8297
Minimum	27.8794
Range	5.9504
Skewness	0.1856
Kurtosis	-0.5743
25% Percentile	29.6828
75% Percentile	31.3082
Percentage Error Precision at 95% Confidence	0.2308%

Baseline Run: Mean of 30.4831 minutes to pick an item from when an order is placed.

Concluding Remarks

- **Process steps are consistent with current warehouse operations**
  - Verified by warehouse operators
- **Modeling enabled identification of largest contributing factors for each process**
  - Varying operator skillsets
  - Varying pick items (low vs. high shelves, easier vs. more difficult items to pull)
  - Varying distances of pick item from forklift storage location
- **Process baselining helped bring clarity to warehouse management operations**
- **Fault Tree Analyses uncovered potential failure modes and their probability of occurrence**
  - Mitigating steps can be put into place to reduce the likelihood or consequence
- **Schedule analysis applied quantitative methods**
  - Establishes benchmarks that operators can assess against

Contact Information

Thank you for your time

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