# Industrial Strength Mine & Extraction Simulation

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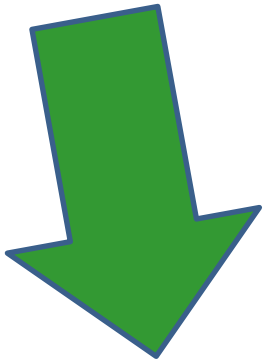
# Optimization

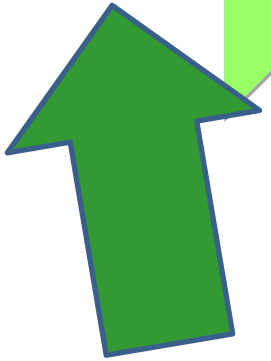


## Operational Level

Haulage → Mine to Mill → Reconcili-ation

## Mine Planning & Production Scheduling

Long-Term → Medium -Term → Short - Term

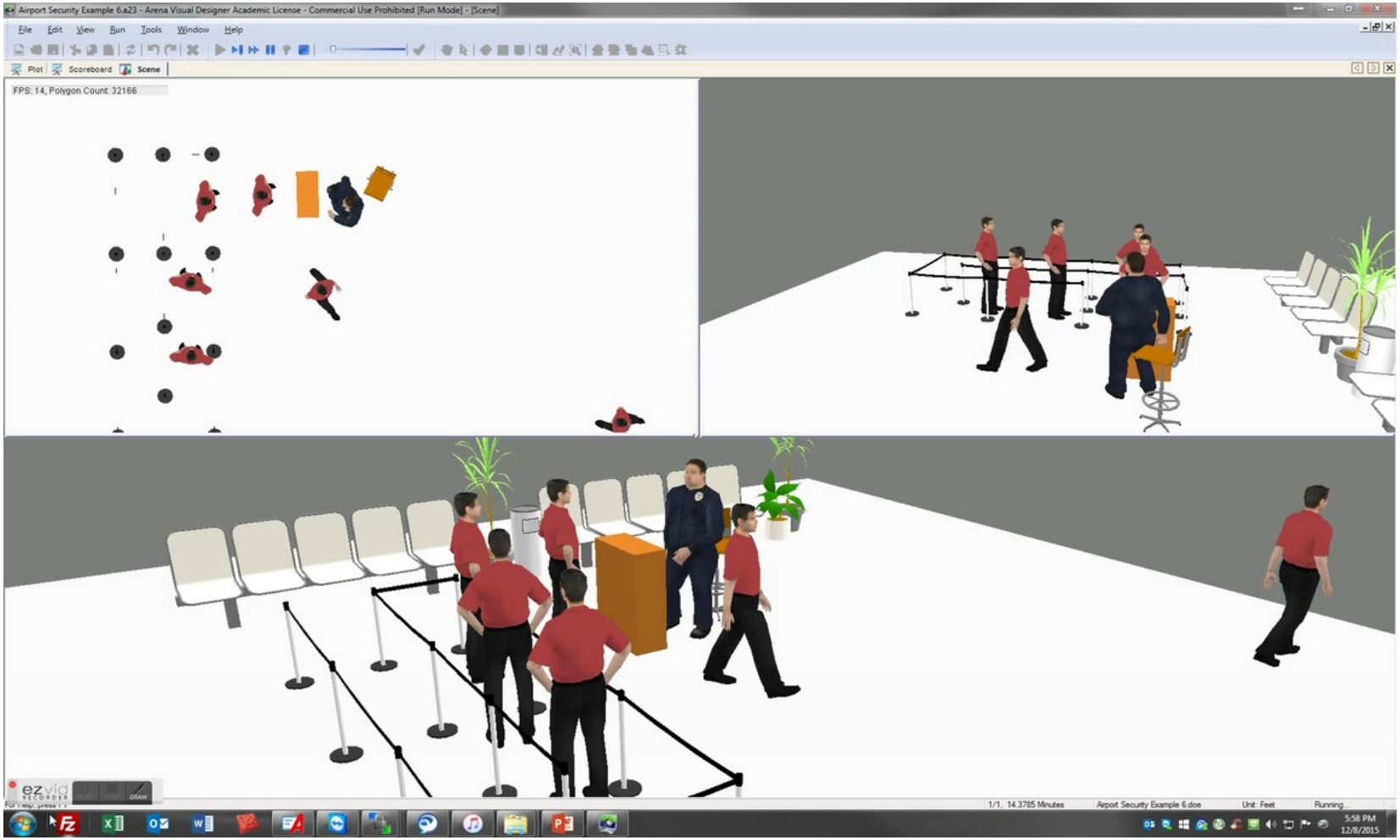


## Simulation

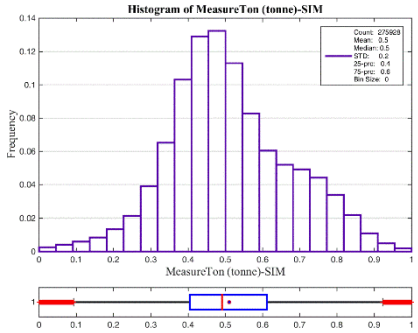
# Background & Introduction

# What is Discrete Event Simulation?

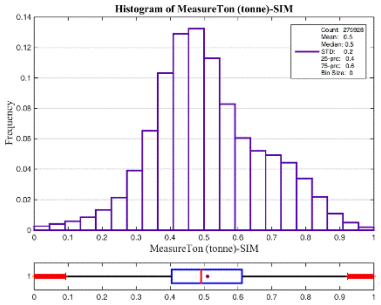
# Airport Check In Model - Animation



# Discrete Event-Simulation




Real-World System

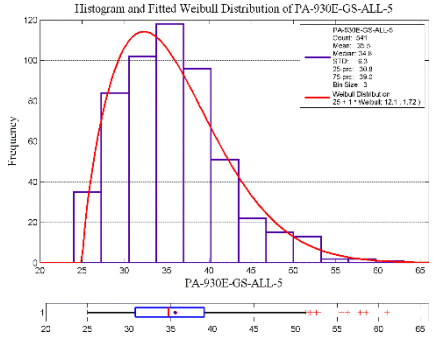



**N input Parameters**

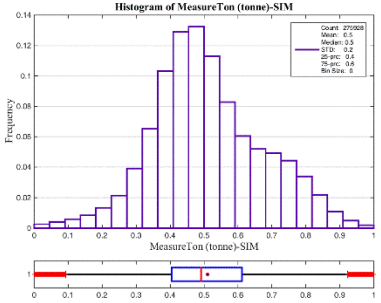
**Time**

**K output performance measures**

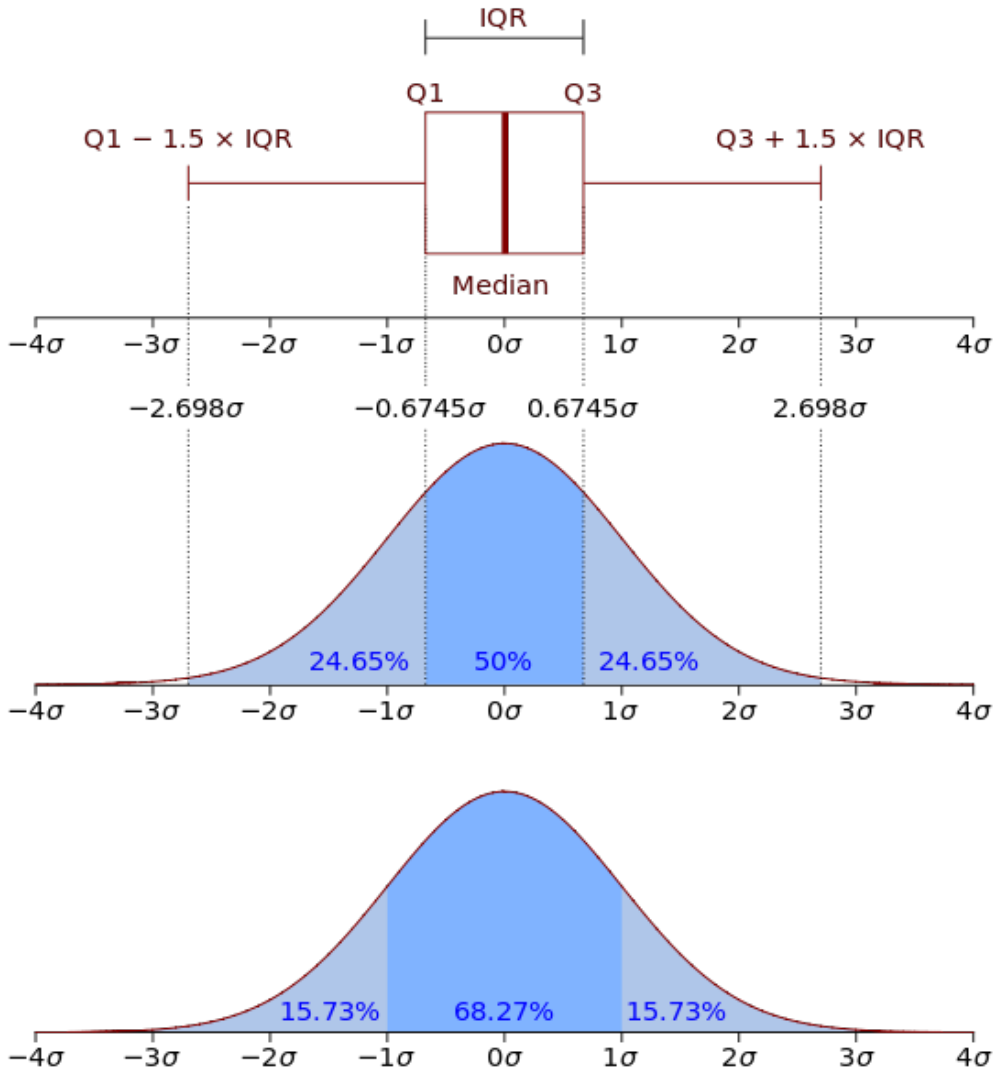
**Mimics the System**




Simulation Model



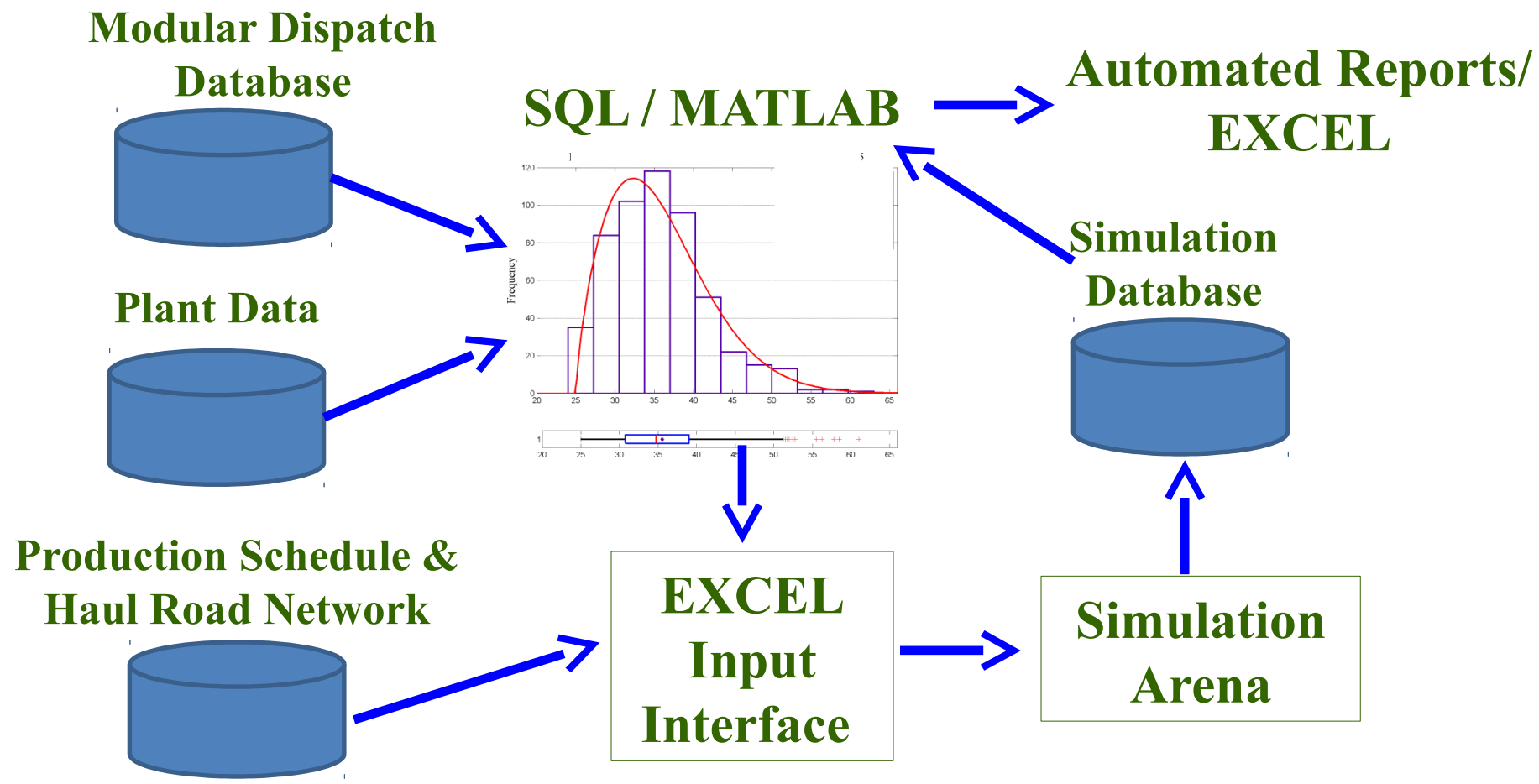
# Uncertainty ⟶ Simulation



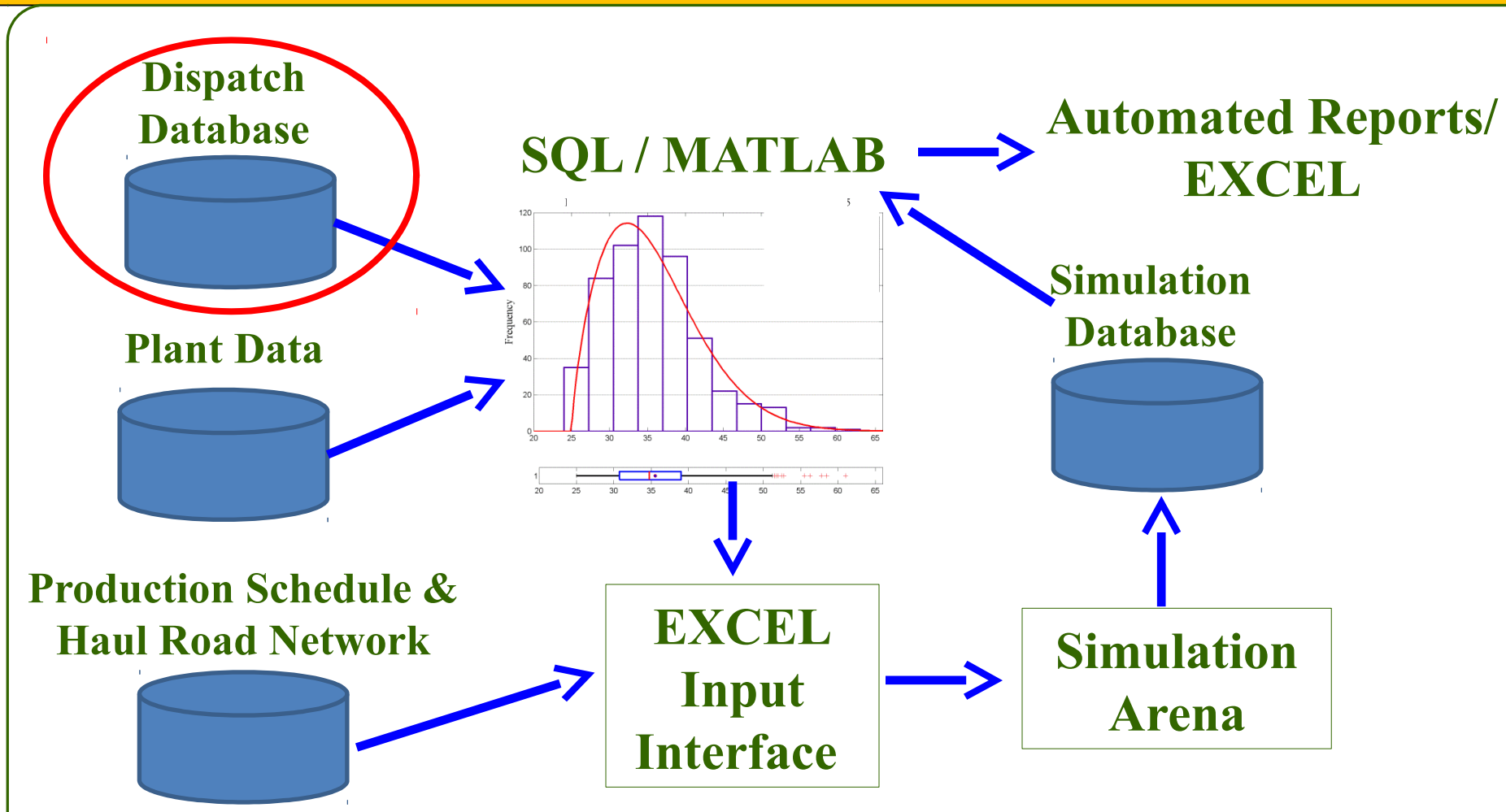

**Boxplots**

# Mine & Extraction Simulation

# General Workflow



# Historical dispatching data



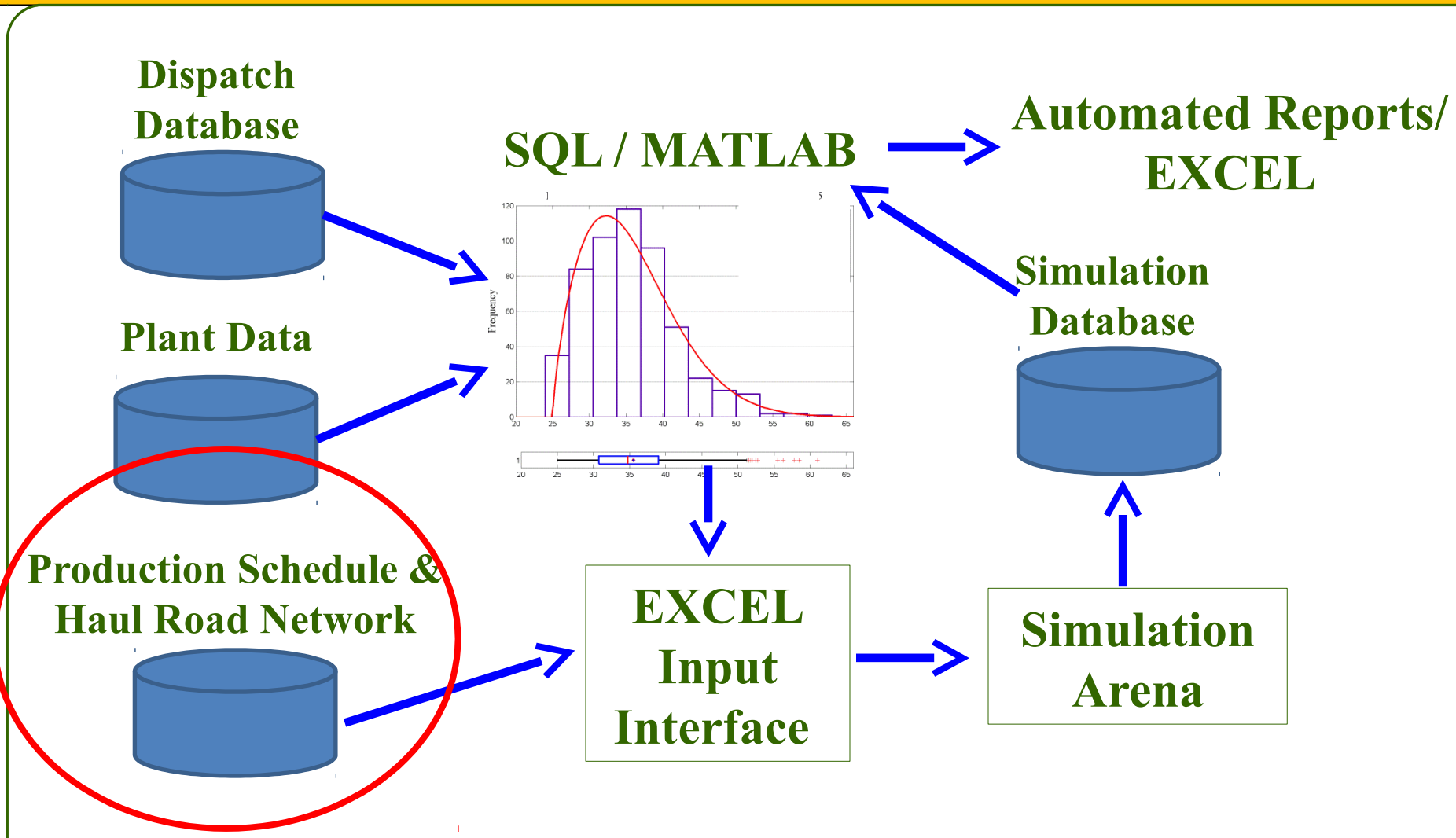
# Historical Dispatch – Production Database

- Time (Day, Hour, Shift),
- Queue Time,
- Spot Time,
- Load Time,
- Bucket Tonnage,
- Haulage Time - Full & Empty,
- Effective Flat Haul - Loaded & Empty
- Truck Speed - Loaded & Empty
- Backup Time,
- Cycle Time,
- Shovel Location,
- Dump Location,
- Grades / Recovery,
- Interrupted Haul / Non Interrupted Haul

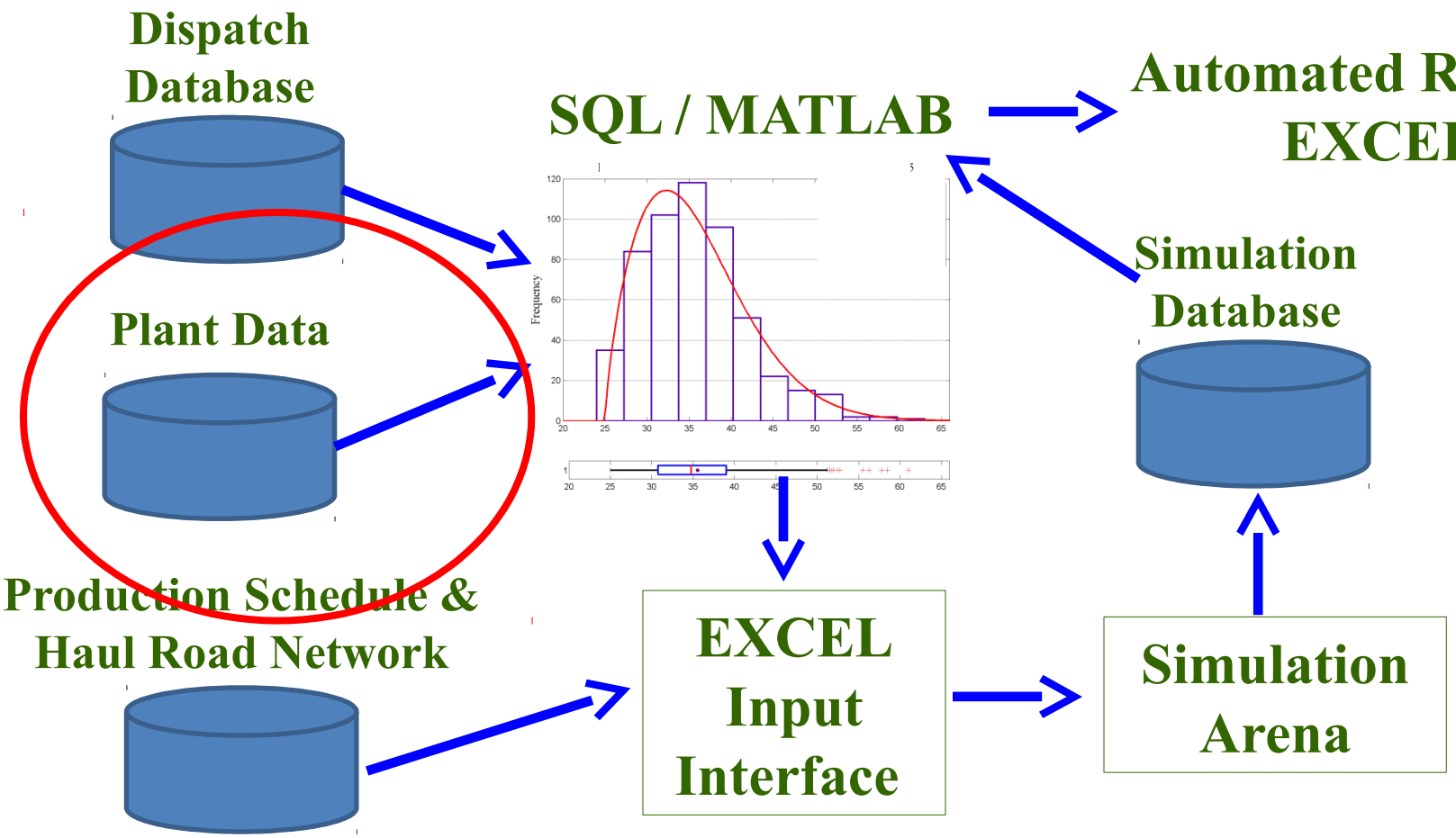
# Historical Dispatch – Activity Database

- Time Stamp
- Equipment Type & Unit
- Start time - End Time / Duration
  - Uptime & Downtime (MTBF / MTTR)
- Reason Codes – + M Regrouped into N New Groups
- Categories – 8 Categories
  - 2 Ops Delay
  - 3 Ops Stand By
  - 4 Short Down
  - 5 Down for Service
  - 6 Down Technical
  - 7 Down Waiting
  - 8 Out of System

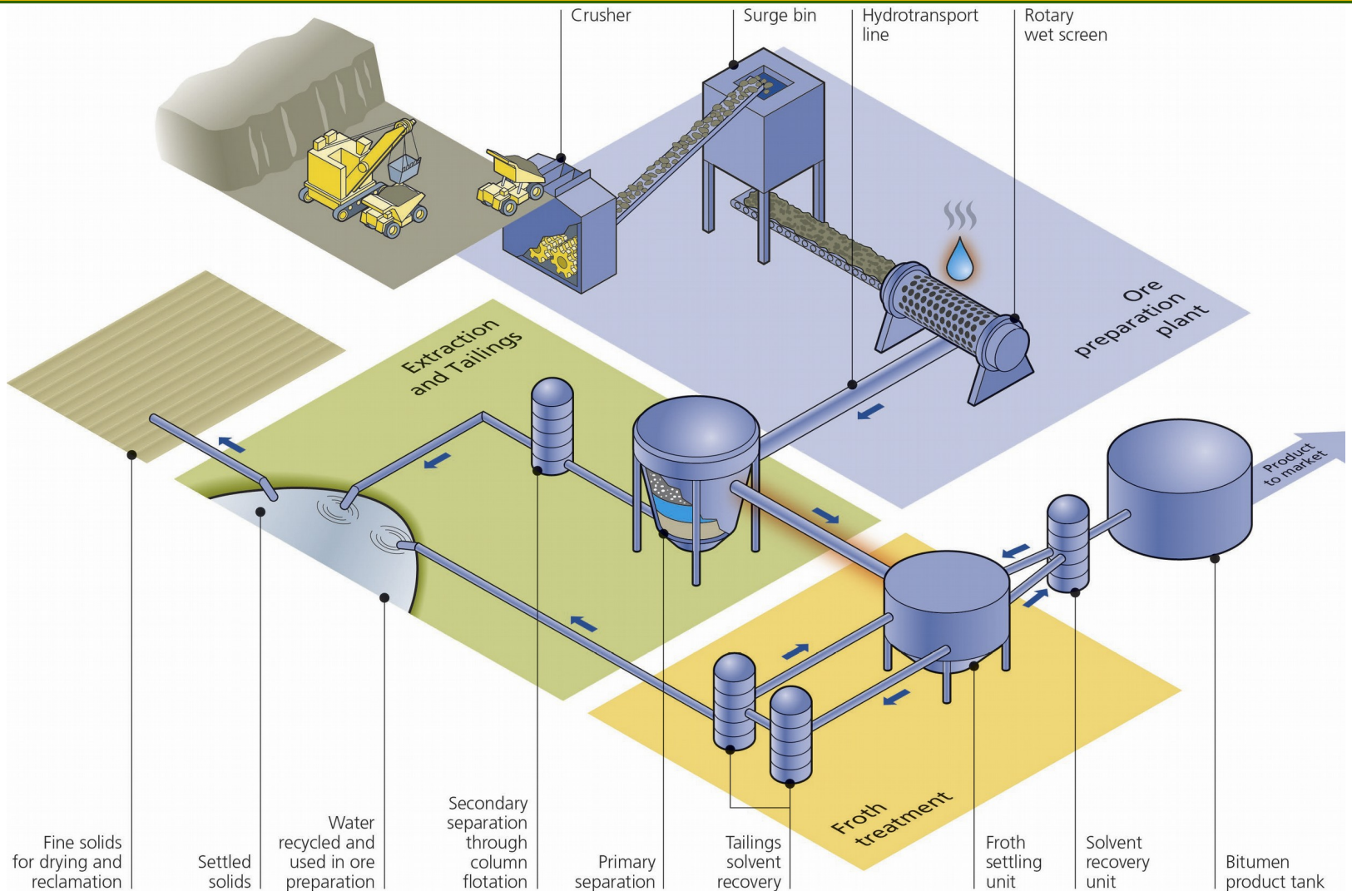
# Short-term Mine Plans / Haul Roads



# Crusher and Plant Information

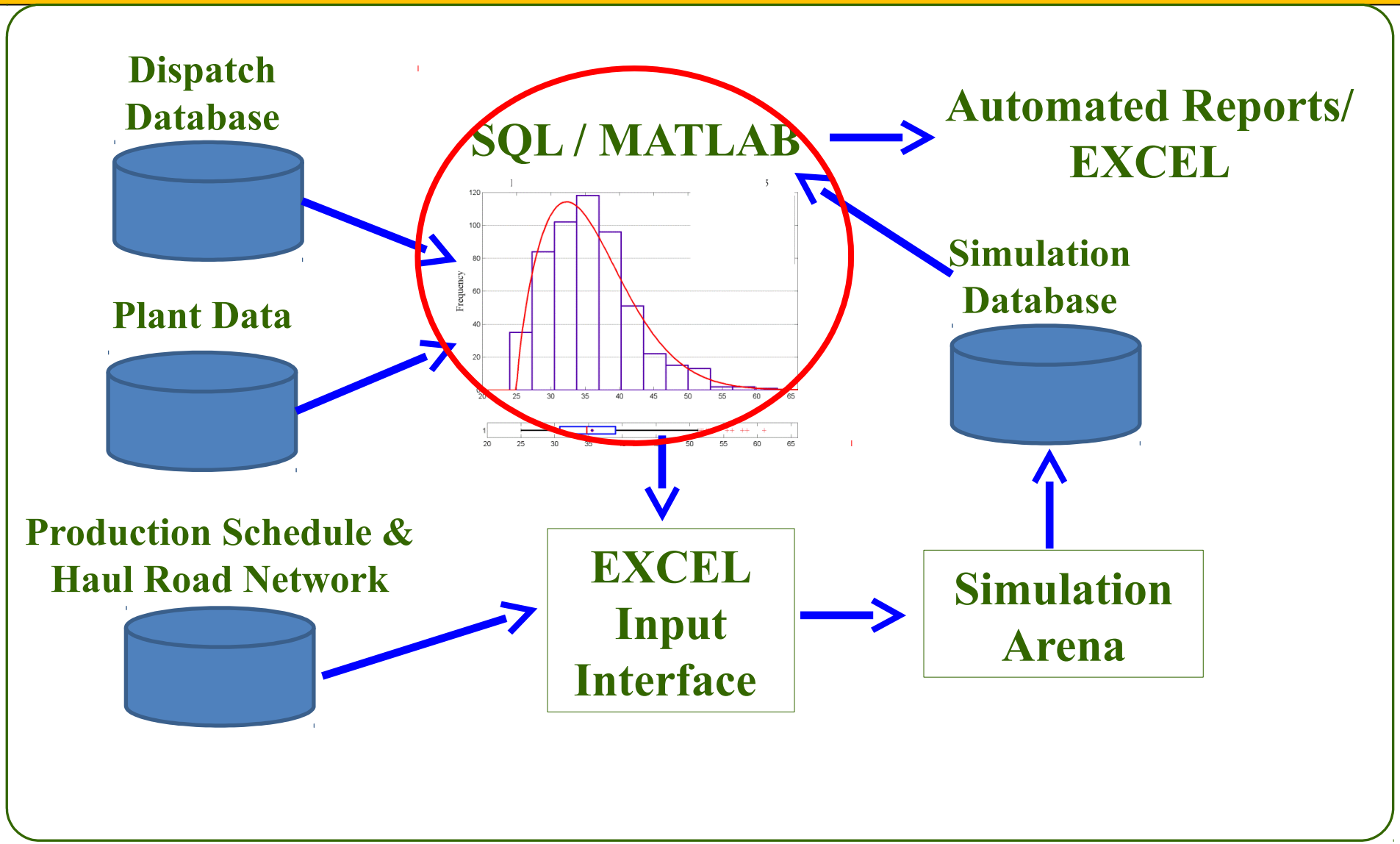


# Plant Data

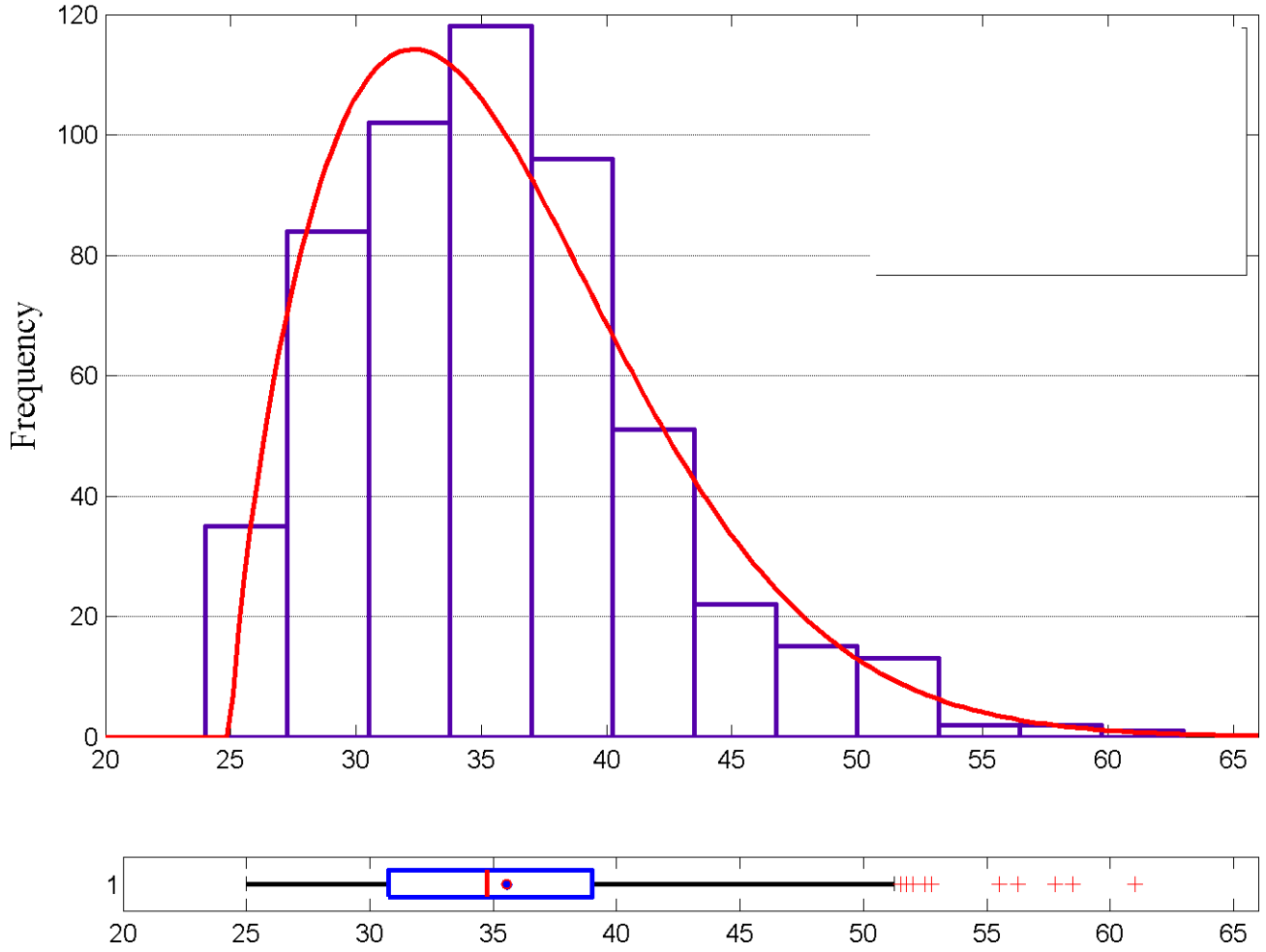



Source: http://forthills.suncor.com/images/general/Fort_hills_mining_process.pdf

# Fitted Distributions on Data



# Fitted Distribution on Historical Data



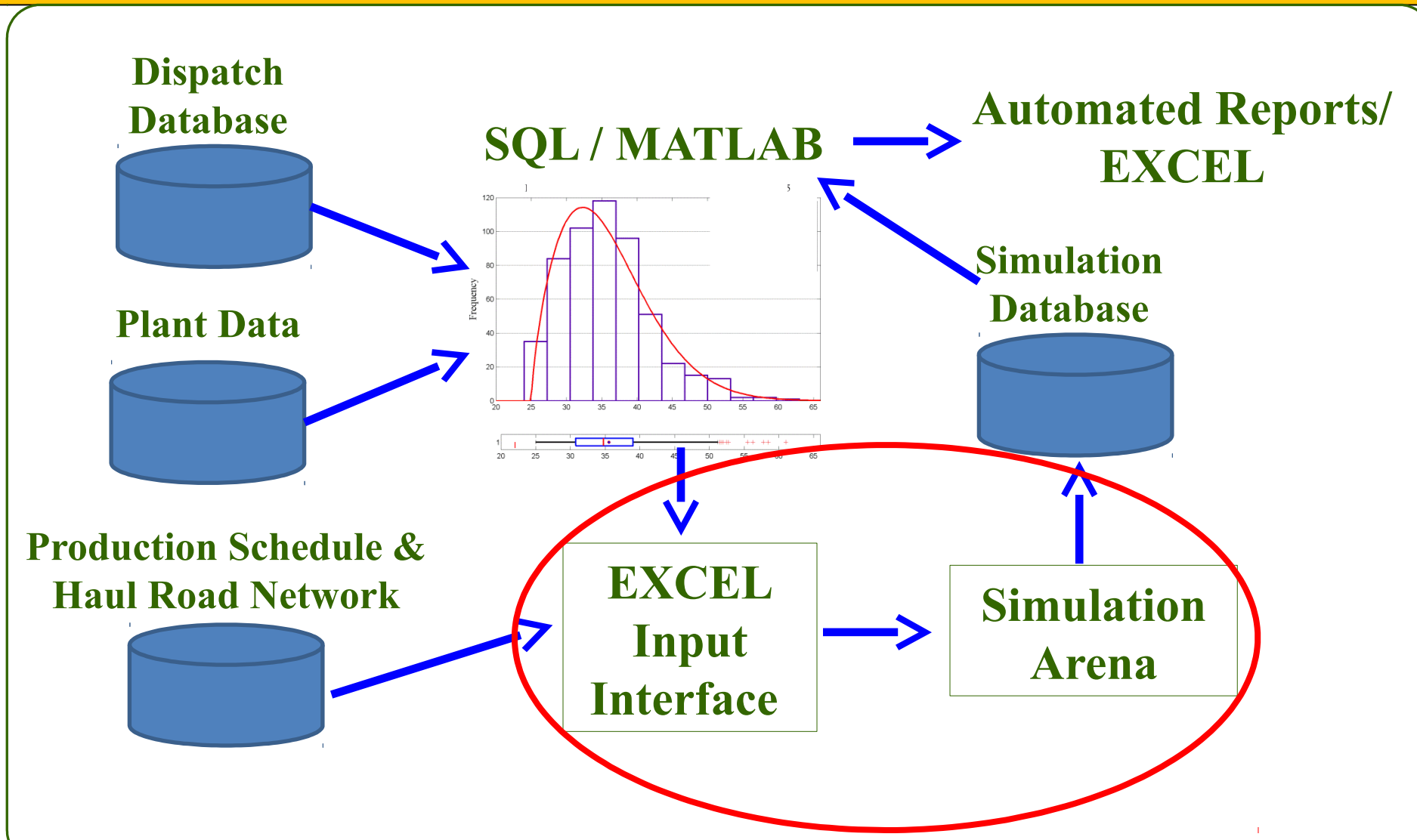
# Fitted Distribution on Historical Data

| Parameter | Based on (Filters) | Num |
|---|---|---|
| Truck – Shovel Prob | Shovels types | 12 (D) |
| Truck – Material Type | Material types Prob | 9 (D) |
| Dump Times | Truck types & N Dumps | 75 (C) |
| Truck (Down/Up Times) | N Truck types & M Failure types | 168 (C) |
| Shovel (Up/Down Times) | N Shovel types & M Failure types | 152 (C) |
| Spot Times | N Shovel types & M Truck types | 12 (C) |
| Bucket Count Probabilities | Shovel – Truck – Material – Bucket Count – Season | 288 (D) |

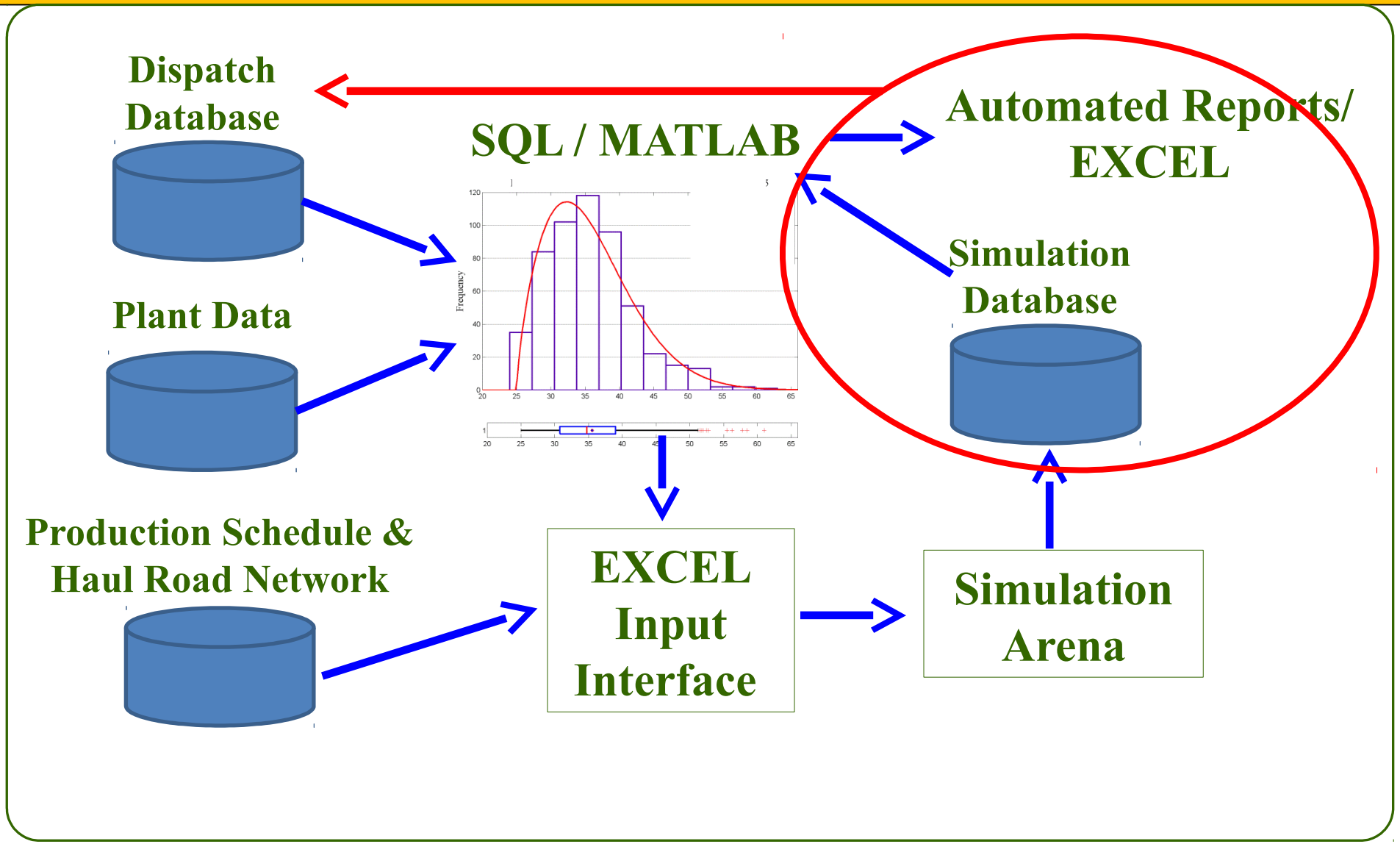
# Fitted Distribution on Historical Data

| Parameter | Based on (Filters) | Num |
|---|---|---|
| Loading Cycle | Shovel – Truck – Material – Bucket Count – Season | 288 (C) |
| Bucket Tonnage | Shovel – Truck – Material – Bucket Count – Season | 288 (C) |
| Truck Speeds | N Truck types (Empty & Loaded) | 6 (C) |
| Throughputs | | 11 (C) |
| Processing Plant Failures | Scheduled and Unscheduled Uptime / Downtime | 22 (C) |
| | **Total Number of Distributions** | **1331** |

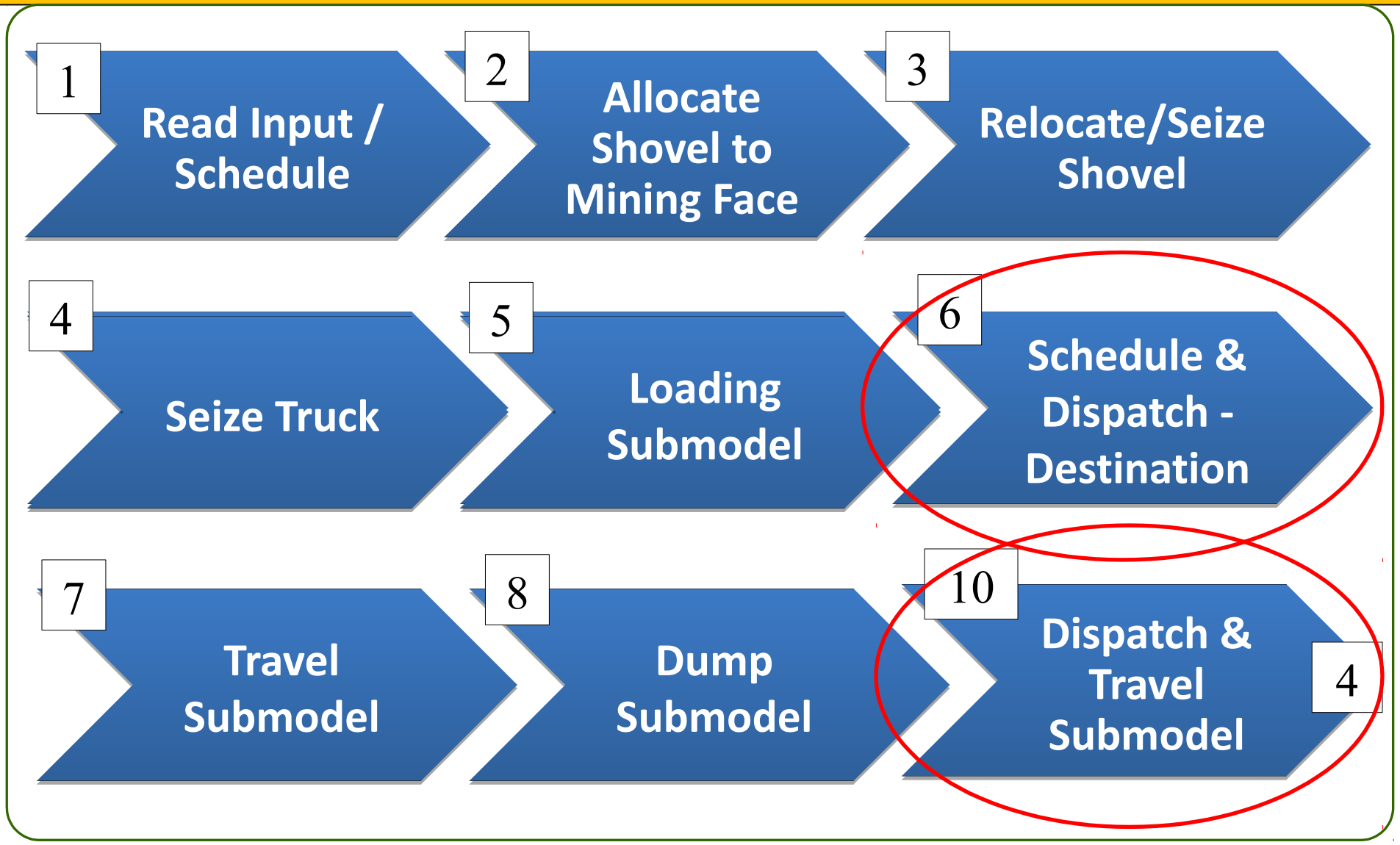
# Fitted Distribution on Historical Data



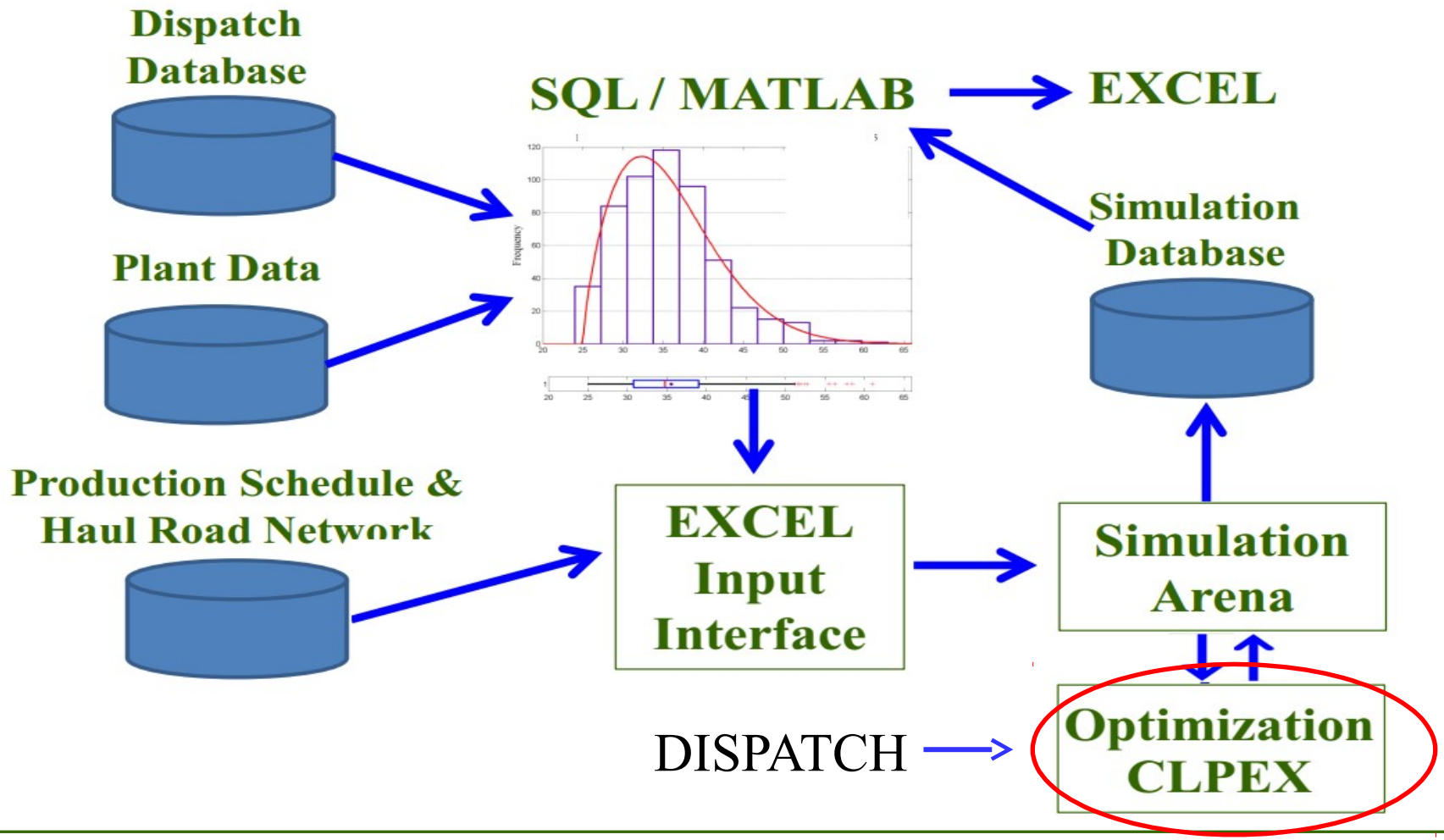
# Simulation vs Data Validation



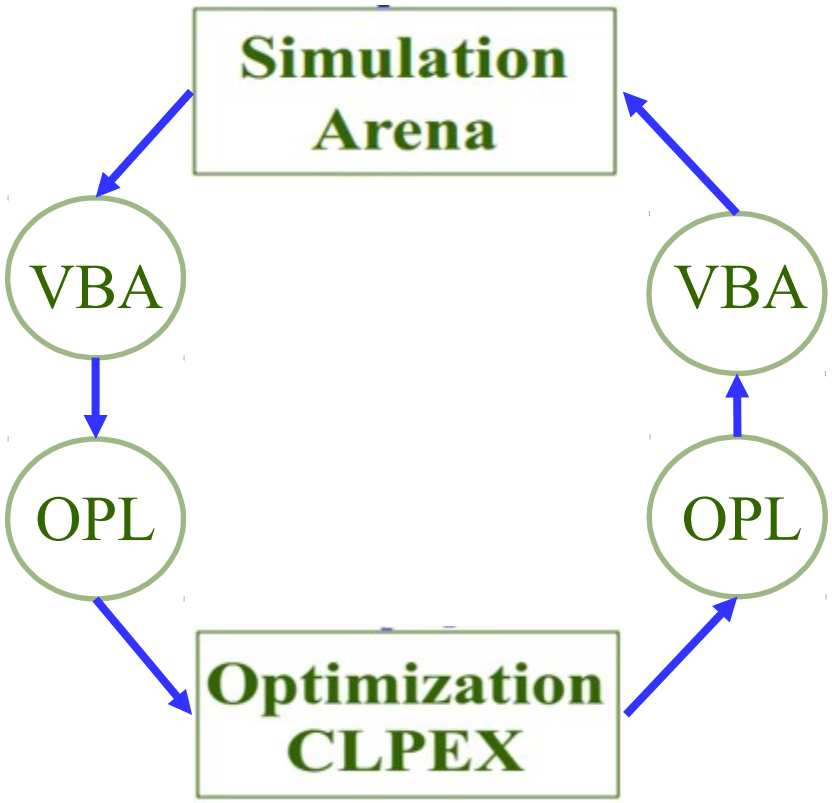
# Simulation High Level Logic

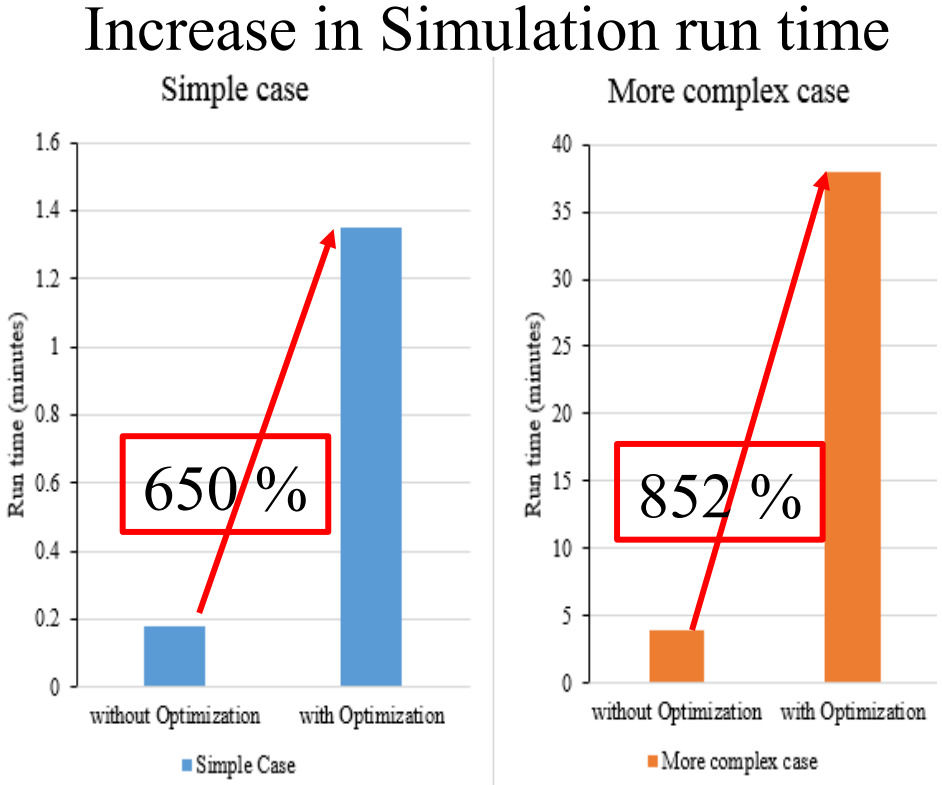


## Embed DISPATCH in simulation

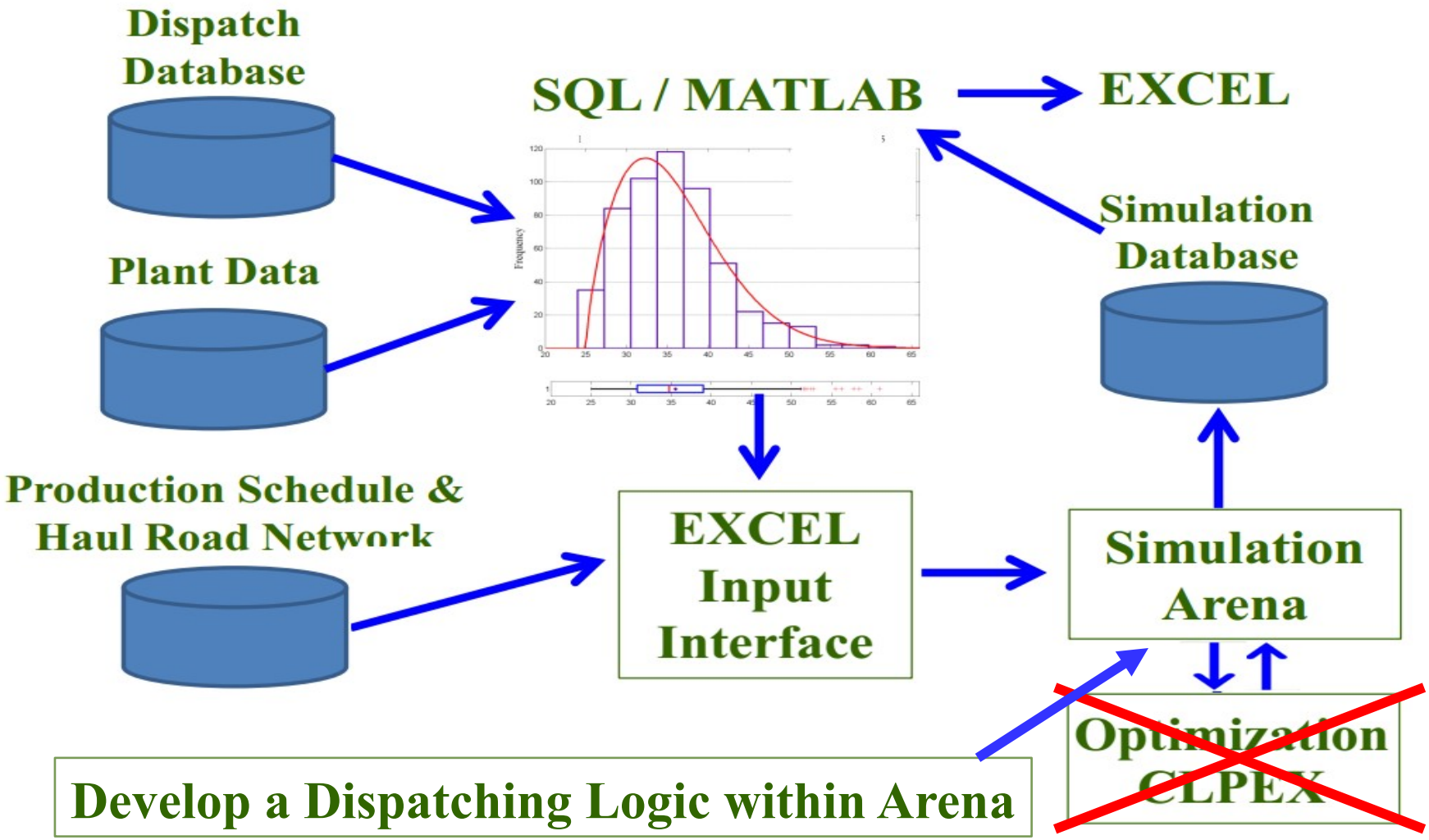


# Embed DISPATCH in simulation (cont'd.)



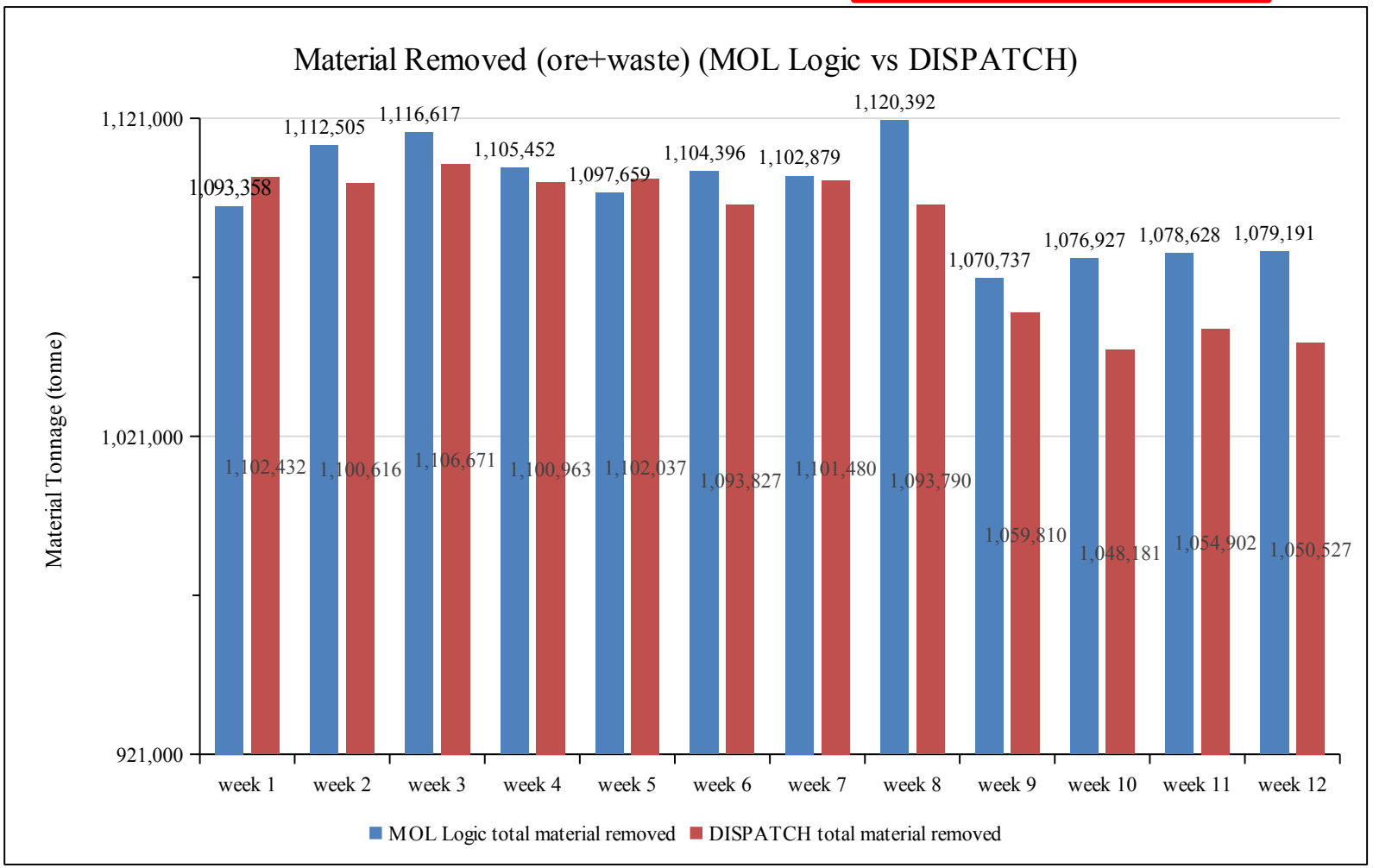
# Embed DISPATCH in simulation (cont'd.)



# Sim Logic vs DISPATCH

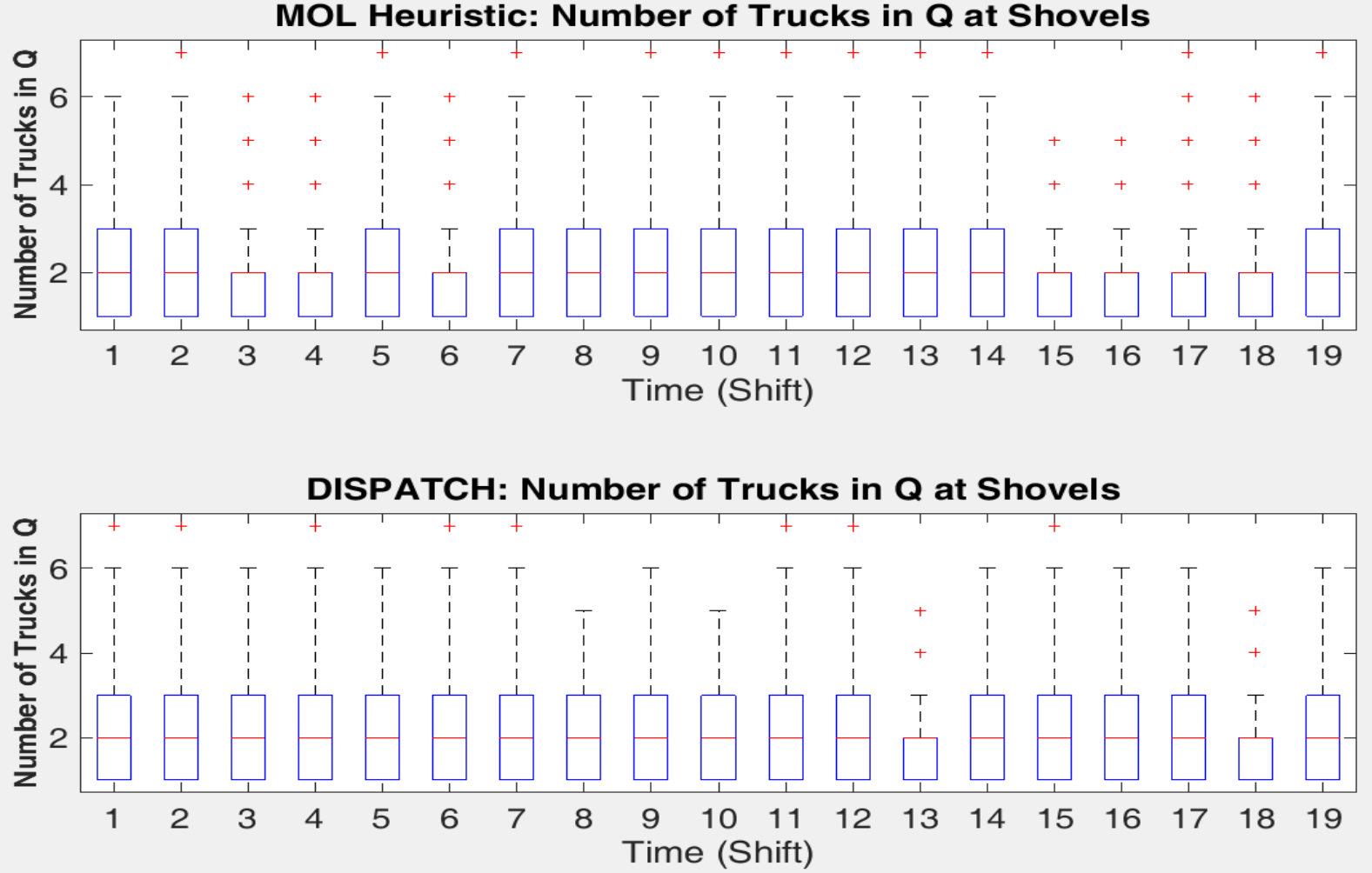
- **Total material removed**

0.9% difference



# Sim Logic vs DISPATCH (cont'd.)

- **Queue Length at shovels**



Validated Results

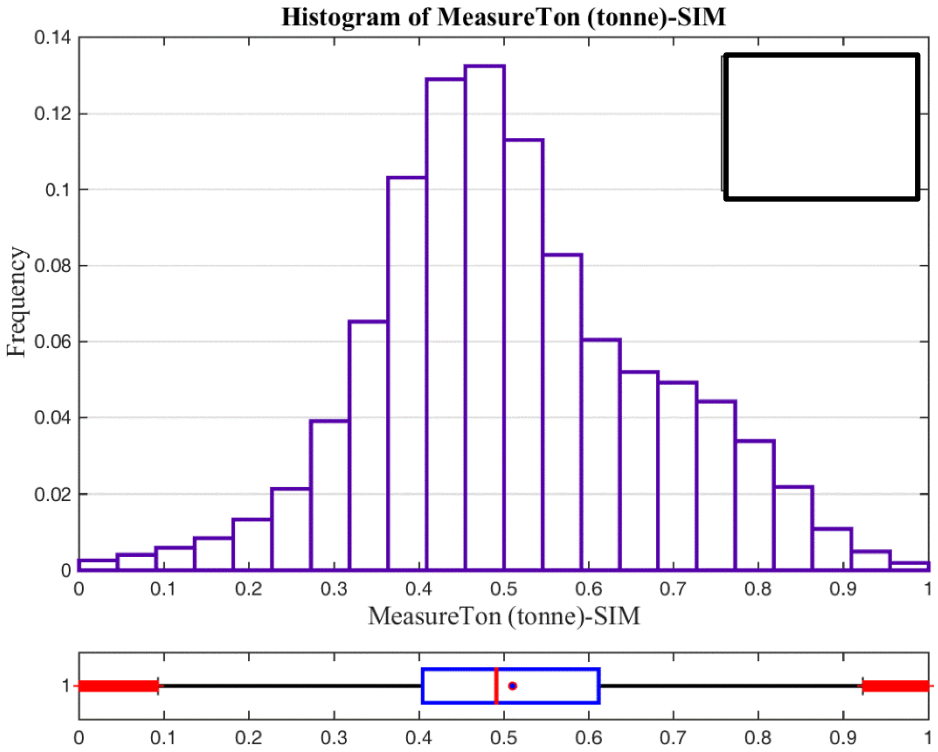
Simulation vs Data

Normalized Results Presented

Quarterly Runs

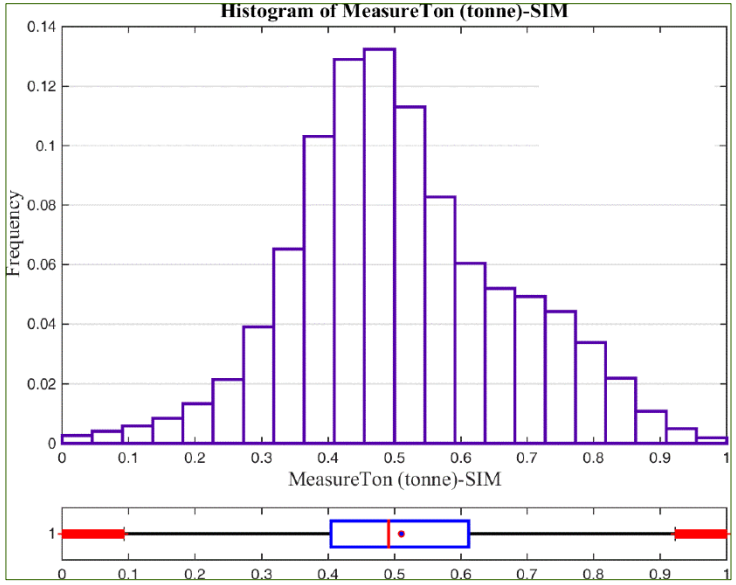
# Output Results

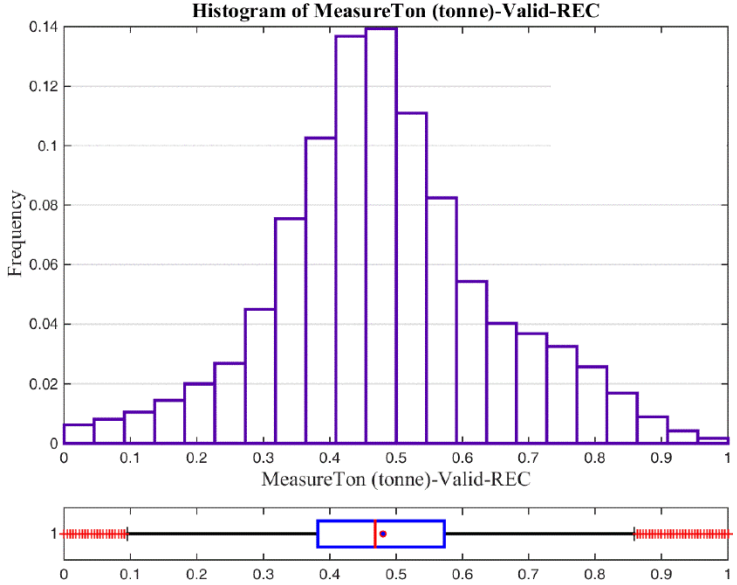
| Count | Min | Max | Range | Mean | Median | STDev |
|---|---|---|---|---|---|---|



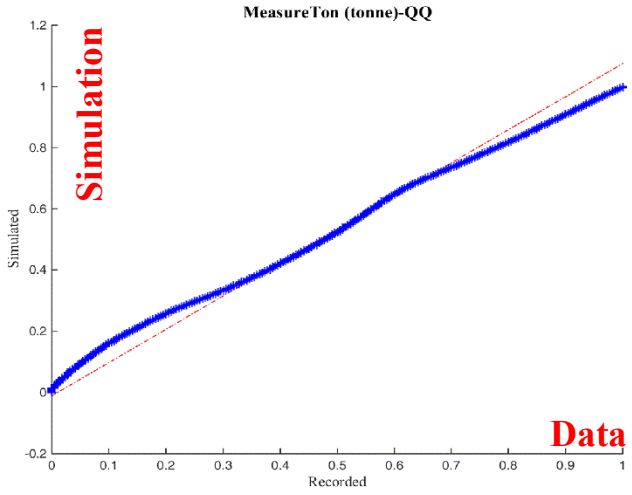

| Summation | 25-Percentile | 75-Percentile | Skewness | Kurtosis | Left Whisker | Right Whisker |
|---|---|---|---|---|---|---|

# Measured Tonne – Truck Loads



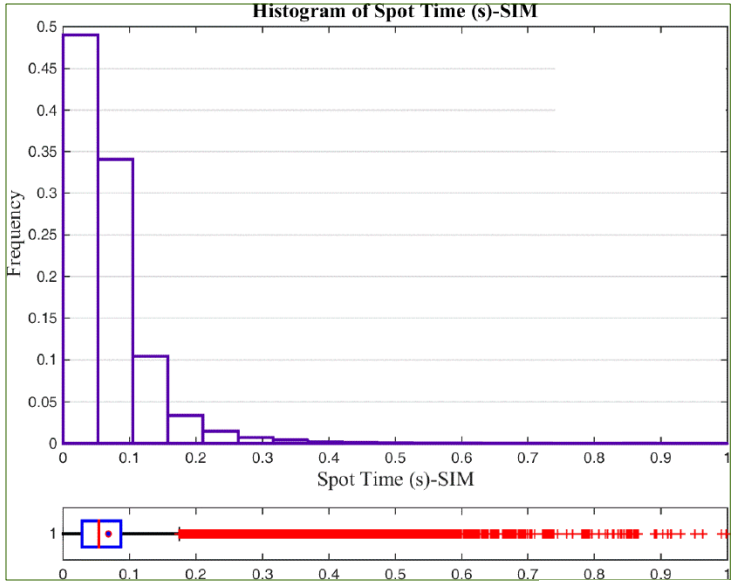




Simulation

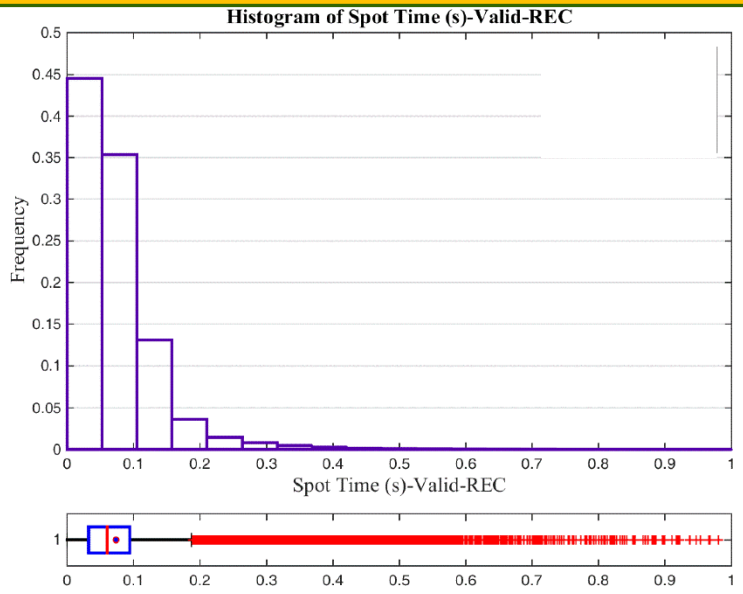



Data

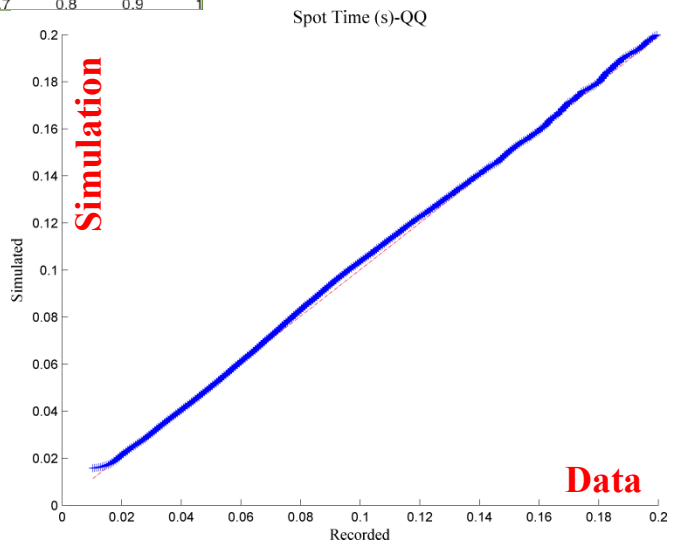
# Spot Time (s)



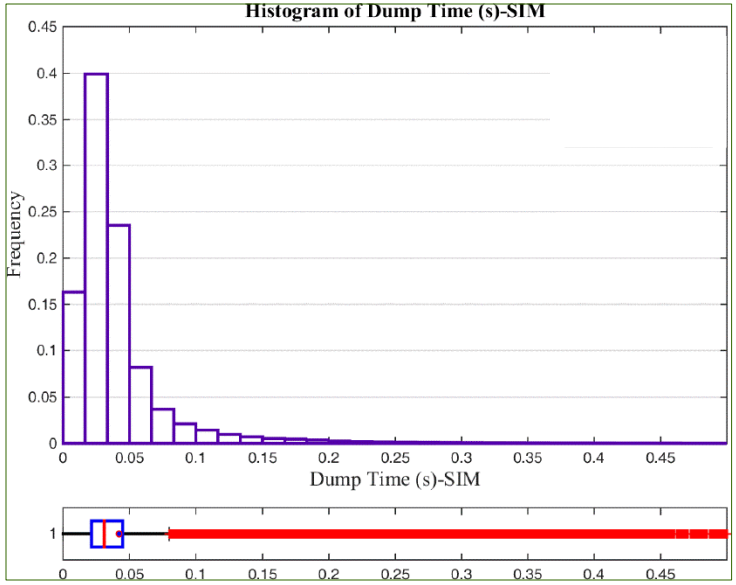

Simulation



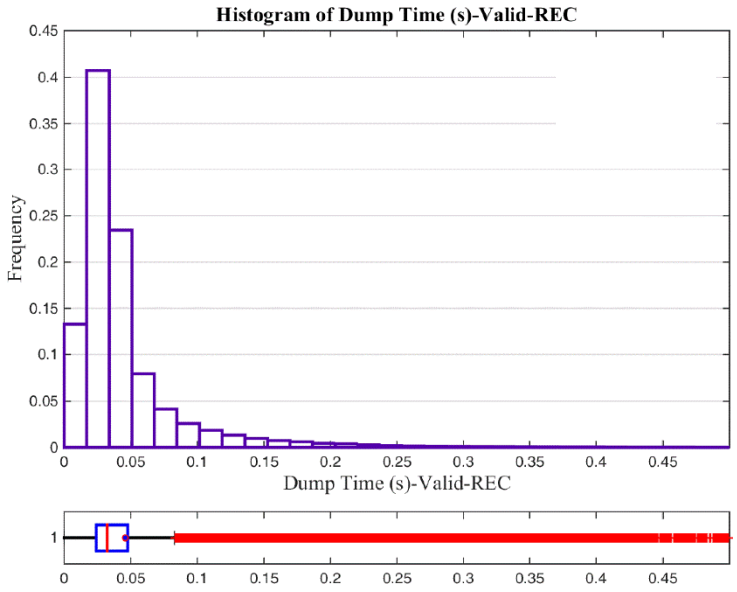

Data



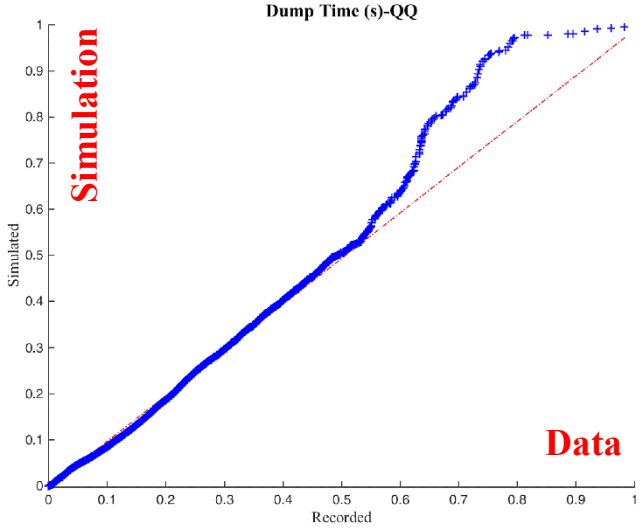
# Dump Time (s)



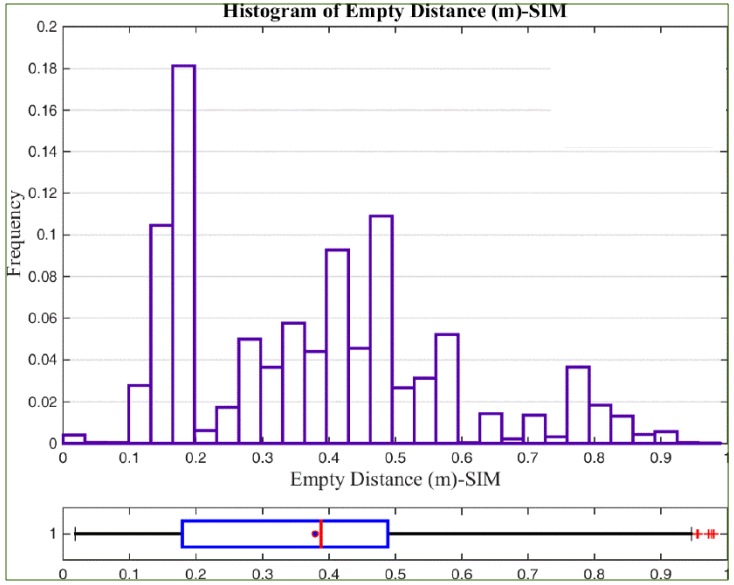

Simulation

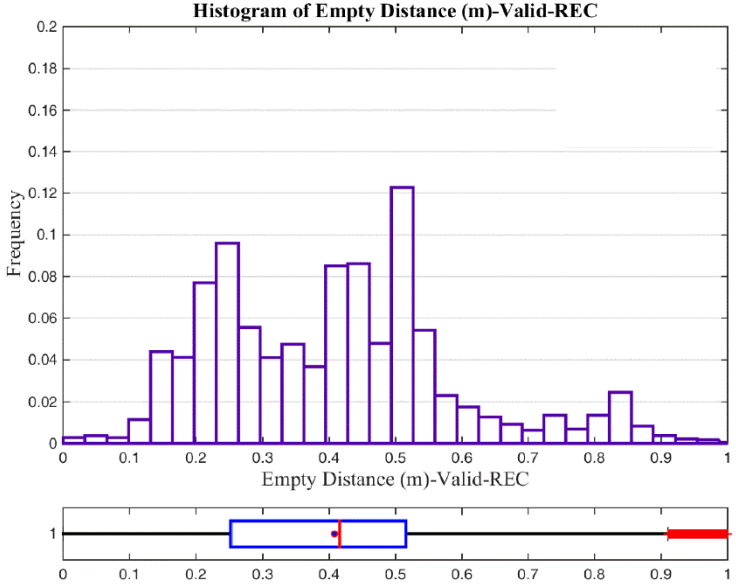



Data

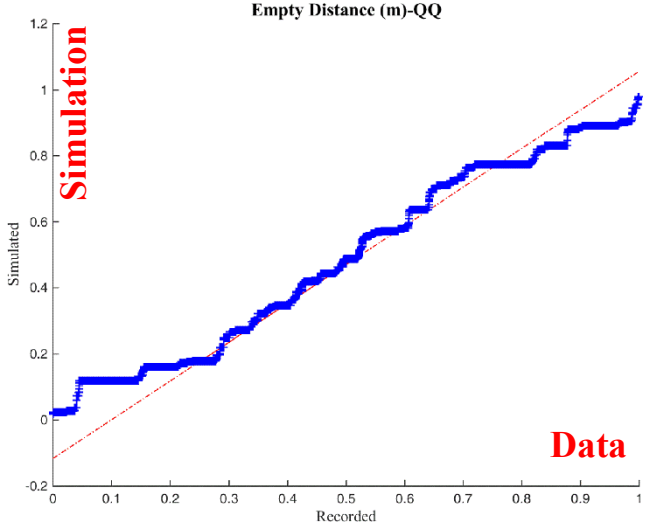


# Empty Distance (m)



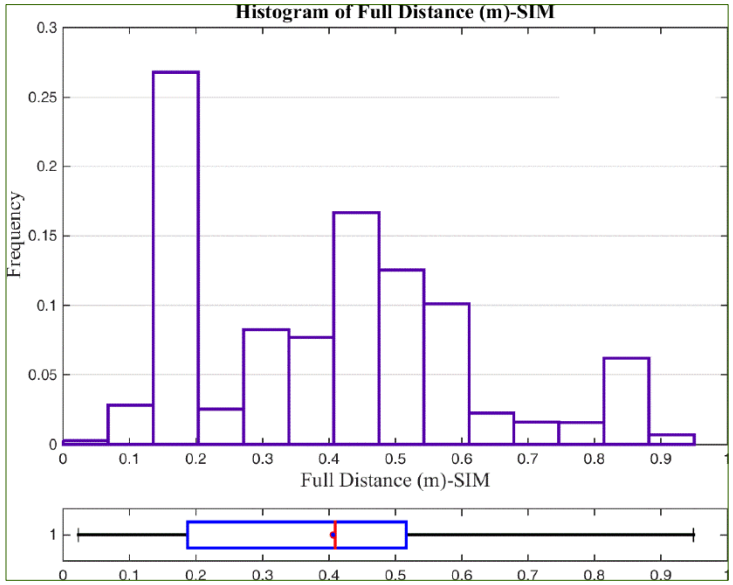




Simulation

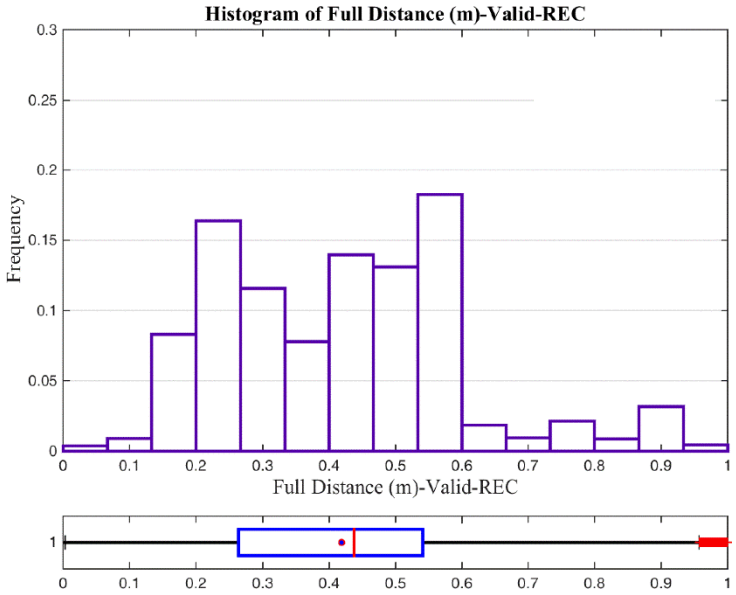



Data

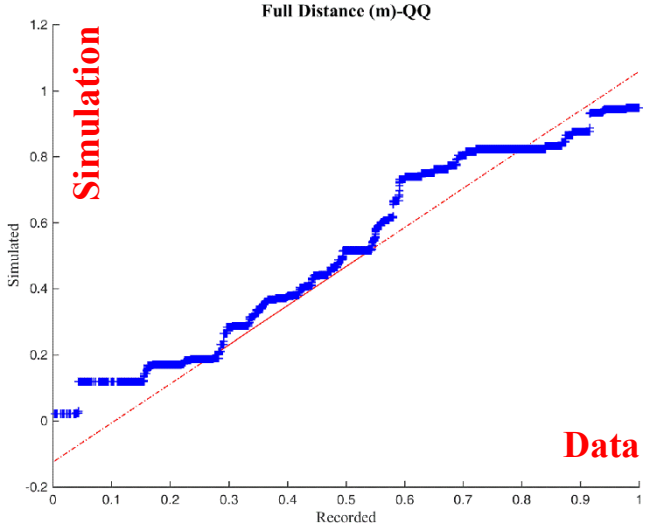
# Full Distance (m)



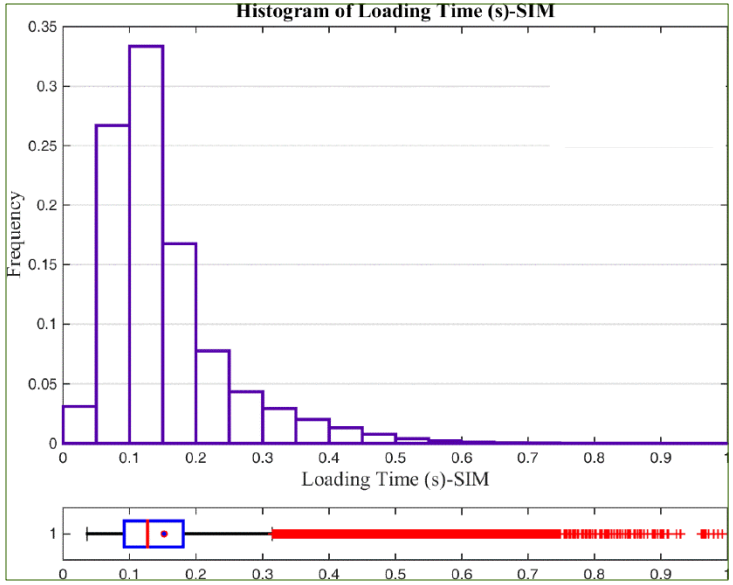

Simulation



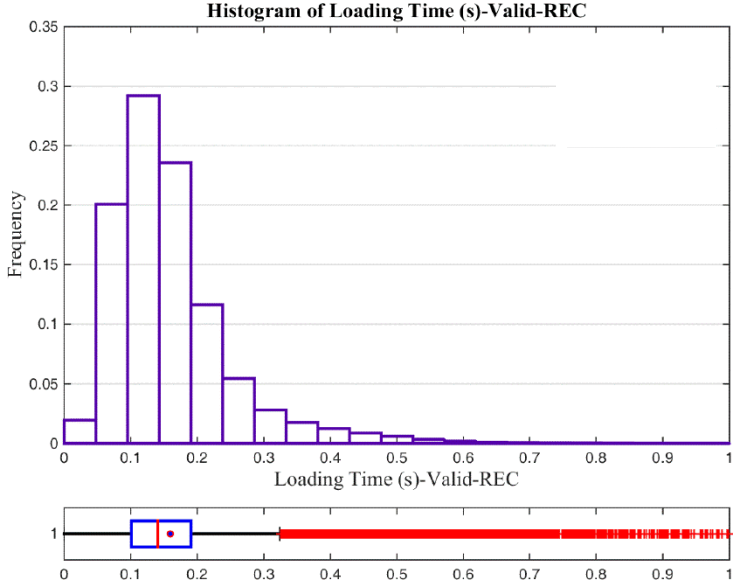

Data



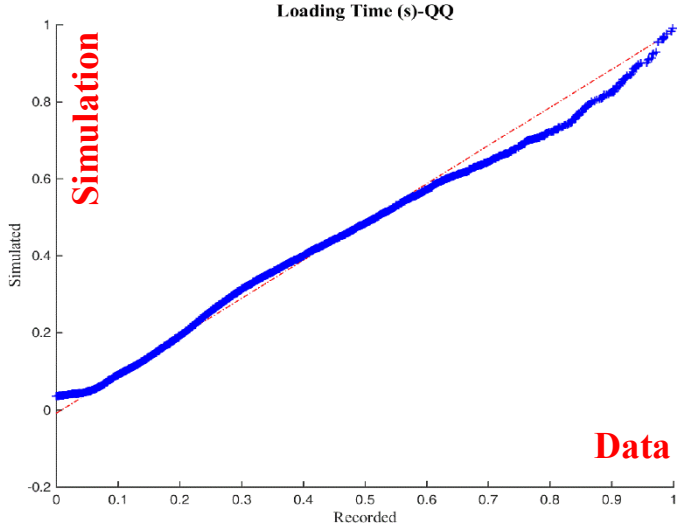
# Loading Time (S)



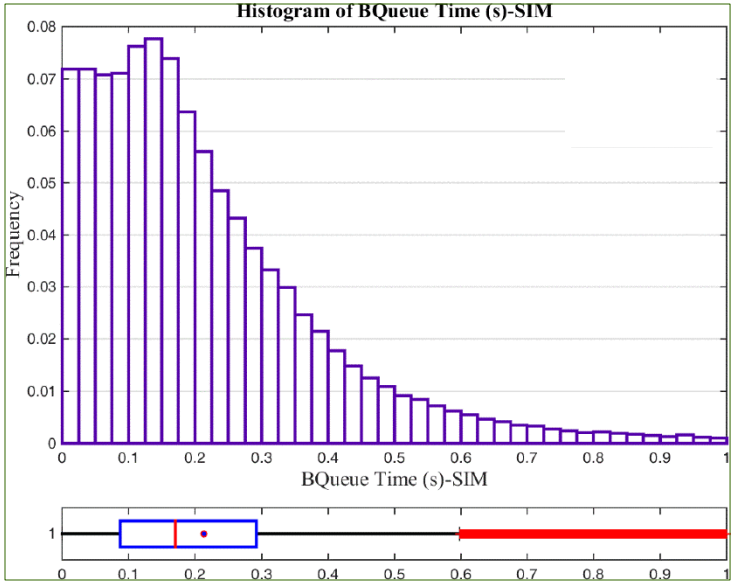

Simulation



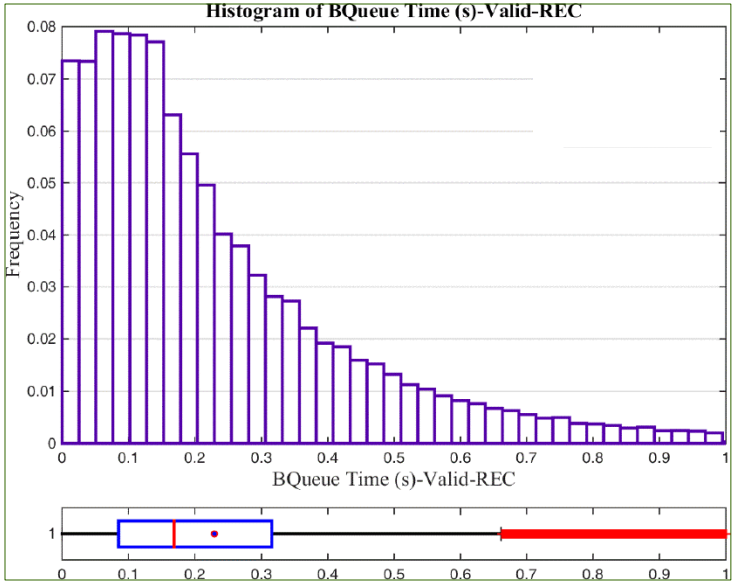

Data



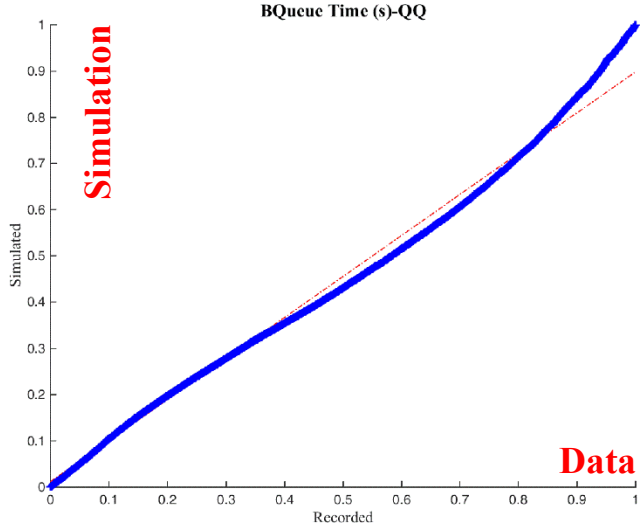
# Queue Time (s) at Shovels



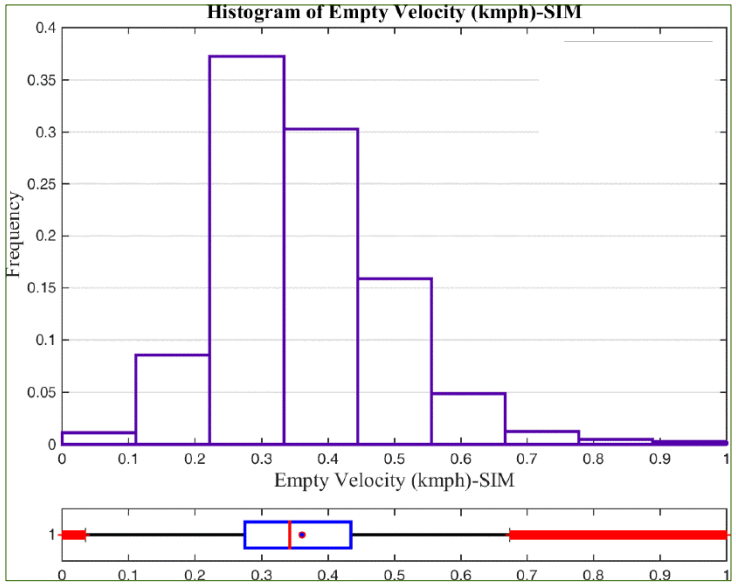

Simulation



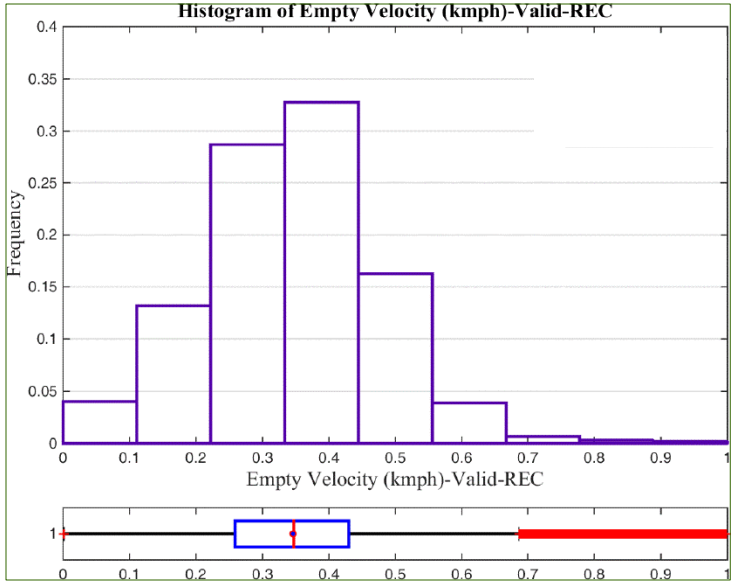

Data



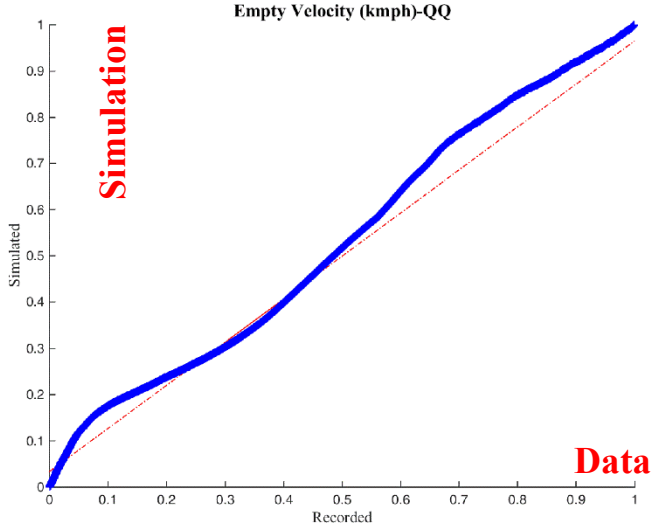
# Empty Velocity (Km/hr)




Simulation




Data



# Simulation vs. Data Validation – Dispatch Records

| | Count | Min | Max | Range | Mean | Median | STDev | Sum | 25-Perctl. | 75-Perctl. |
|---|---|---|---|---|---|---|---|---|---|---|
| Measure Ton (tonne)-Diff% | 1% | 0% | 0% | 0% | 2% | 1% | 0% | 1% | 1% | 2% |
| Empty Distance (m)-Diff% | 5% | 5% | -2% | -4% | -4% | -1% | 8% | 6% | -31% | -3% |
| Full Distance (m)-Diff% | 0% | 50% | -3% | -6% | 0% | 4% | 14% | 1% | -27% | -3% |
| Empty Velocity (kmph)-Diff% | 1% | 0% | 0% | 0% | 2% | 2% | -2% | 1% | 5% | 3% |
| Full Velocity (kmph)-Diff% | 8% | 0% | 0% | 0% | 1% | 0% | 16% | 2% | -4% | 4% |
| Empty Travel Time (s)-Diff% | 1% | 0% | 0% | 0% | -4% | -4% | 15% | 0% | -31% | 2% |
| Full Travel Time (s)-Diff% | 2% | 0% | -14% | -15% | -3% | -2% | 18% | 3% | -7% | 11% |
| Spot Time (s)-Diff% | 8% | 0% | 2% | 2% | 1% | -1% | 2% | 5% | -1% | 1% |
| Loading Time (s)-Diff% | 1% | 12% | 0% | -4% | 0% | -2% | -1% | 3% | -1% | -1% |
| BQueue Time (s)-Diff% | 10% | 0% | 0% | 0% | 5% | 6% | -3% | 8% | 30% | 18% |
| Dump Time (s)-Diff% | 11% | 0% | 0% | 0% | -1% | -3% | 18% | 7% | -25% | -4% |

# Truck KPIs

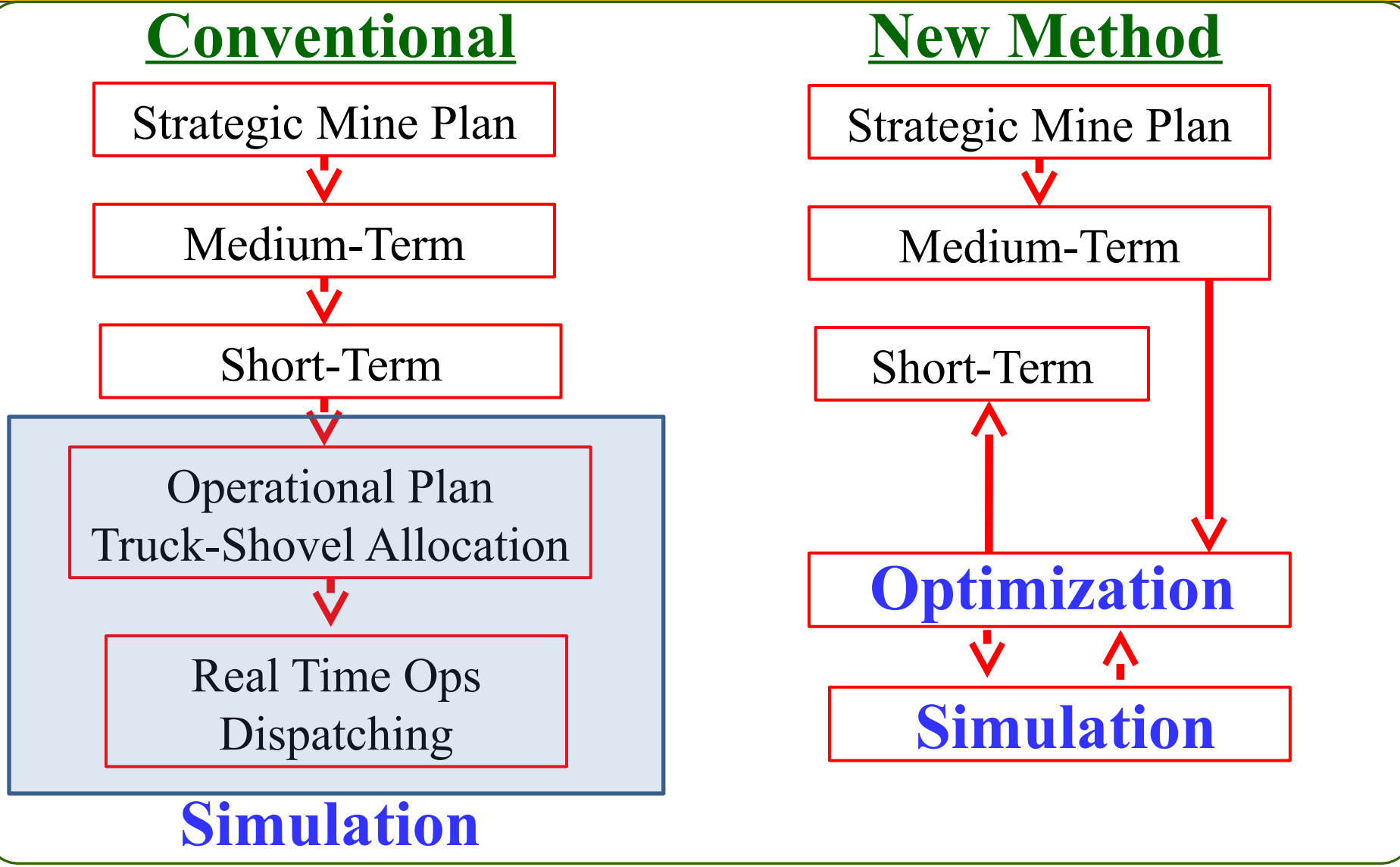
| | Mean | Median | Summation |
|---|---|---|---|
| Ops Delay-Diff% | 1% | 0% | 1% |
| Ops Standby-SIM | -2% | -8% | -2% |
| Short Down-Diff% | -3% | 7% | -3% |
| Down Service-Diff% | 1% | 4% | 0% |
| Down Technical-Diff% | 0% | 5% | 0% |
| Down Waiting-Diff% | -2% | -2% | -1% |
| Operations Time (Available Time)-Diff% | 0% | -1% | 0% |
| Maintenance Time (Down Time)-Diff% | 0% | 7% | 0% |
| Gross Operating Hours-Diff% | 1% | 0% | 1% |
| Physical Availability-Diff% | 0% | -2% | 0% |
| Use of Availability-Diff% | 0% | 0% | 1% |
| Operating Efficiency-Diff% | 1% | 2% | 3% |
| Effective Utilization-Diff% | 0% | 0% | 1% |
| Calculated t/NOH-Diff% | -2% | -2% | -2% |

## Validated Model – Run New Scenarios

# Autonomous Haulage System

# New Developments
# Simulation-Optimization

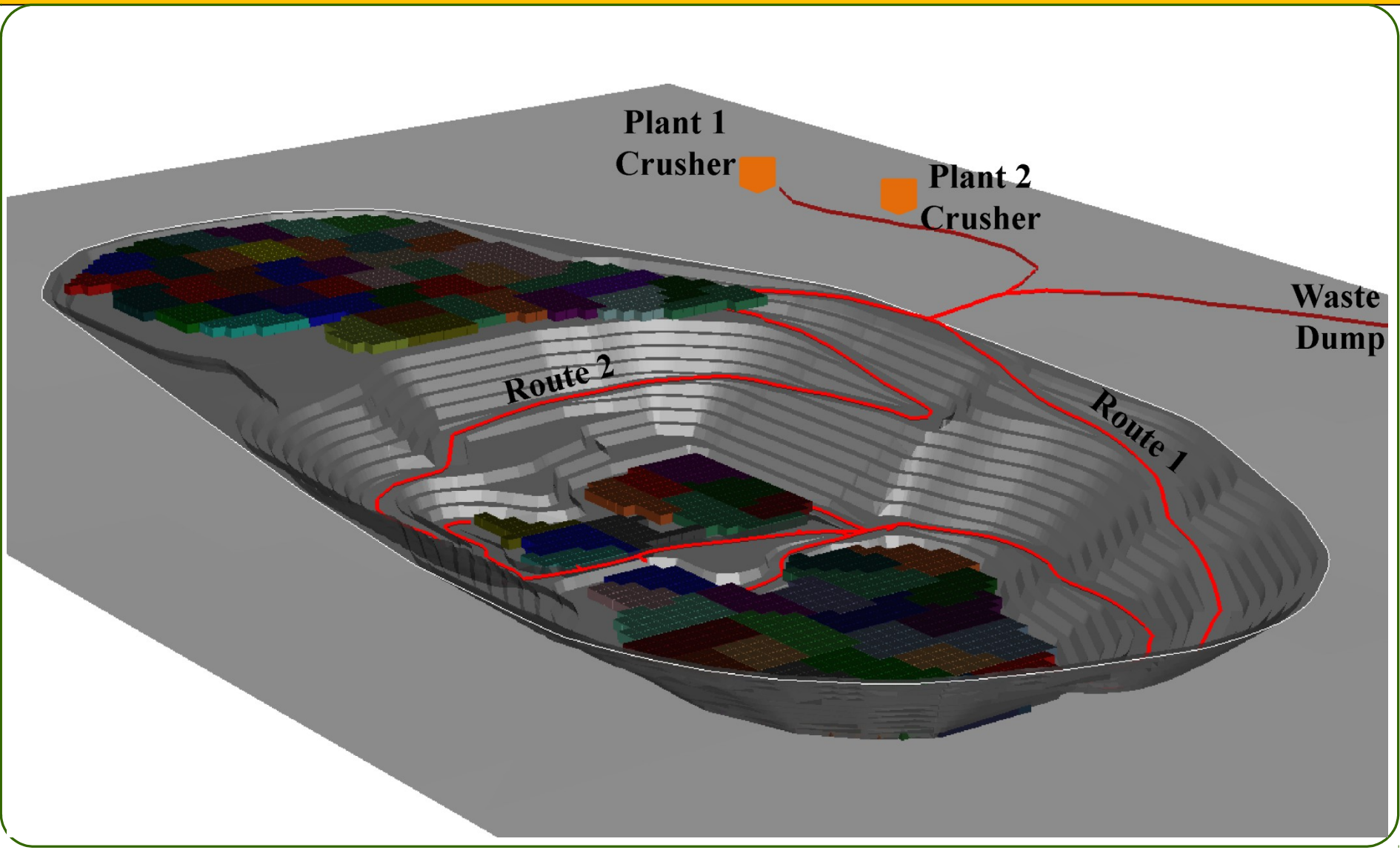
# Simulation-Optimization Approach



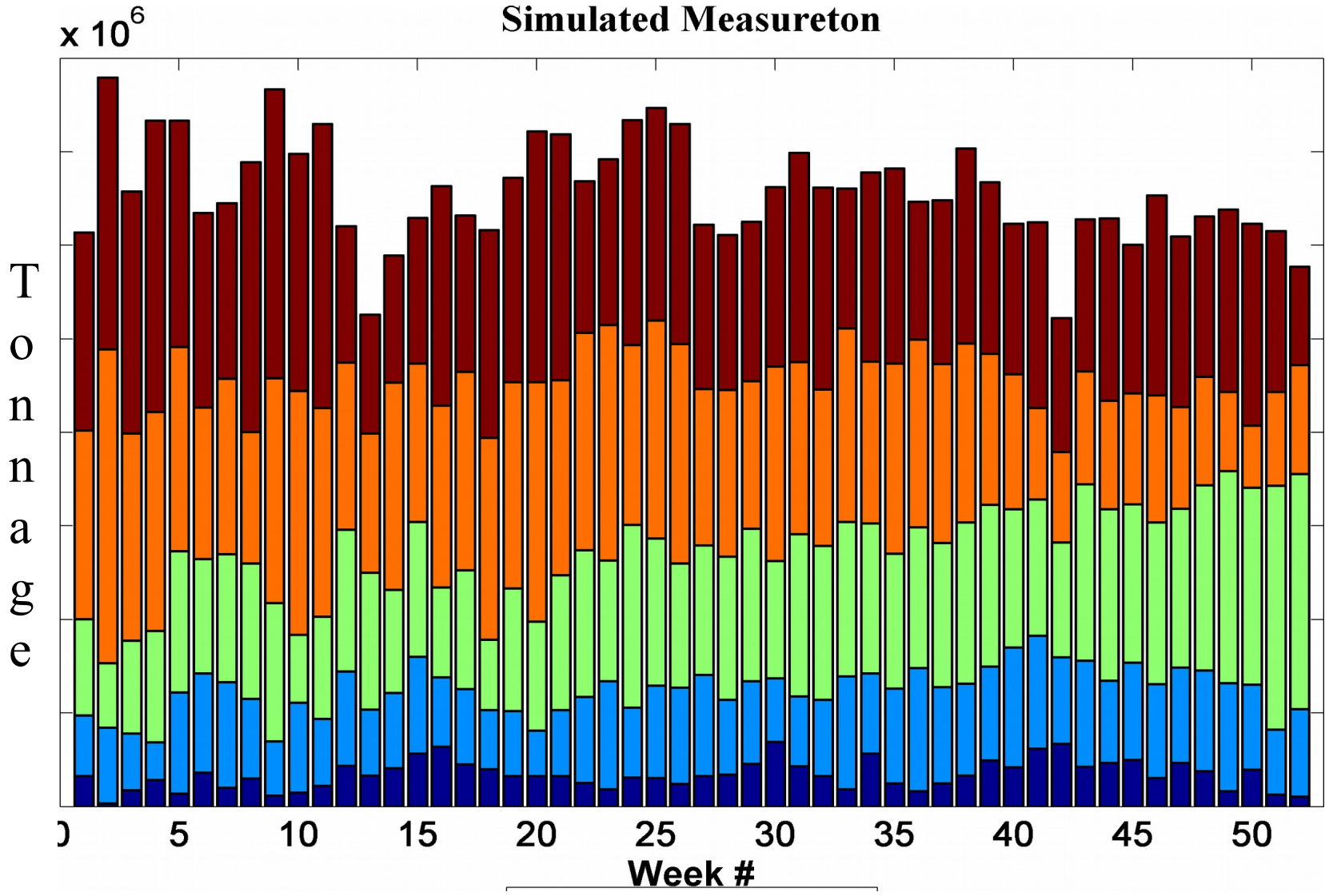
# Simulation-Optimization

- Maximize Production
- Minimize the deviation in tonnage supplied to the processing plants compared to desired tonnage feed
- Minimize the grade deviations at ore destinations compared to desired grades
- Minimize shovel movements

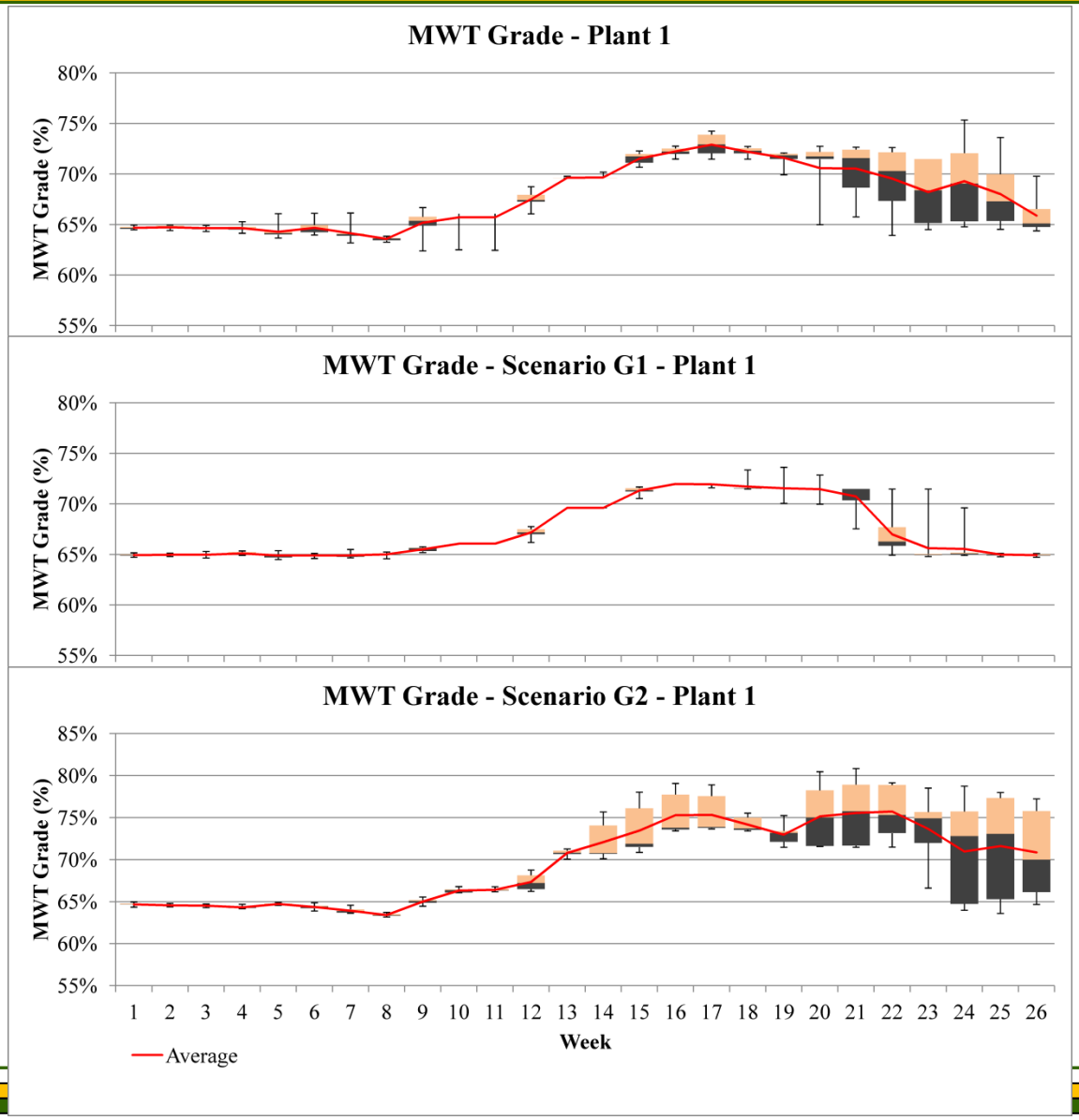
# Implementation – Haulage Planning



# Weekly Simulated Production



# Implementation – Grade blending

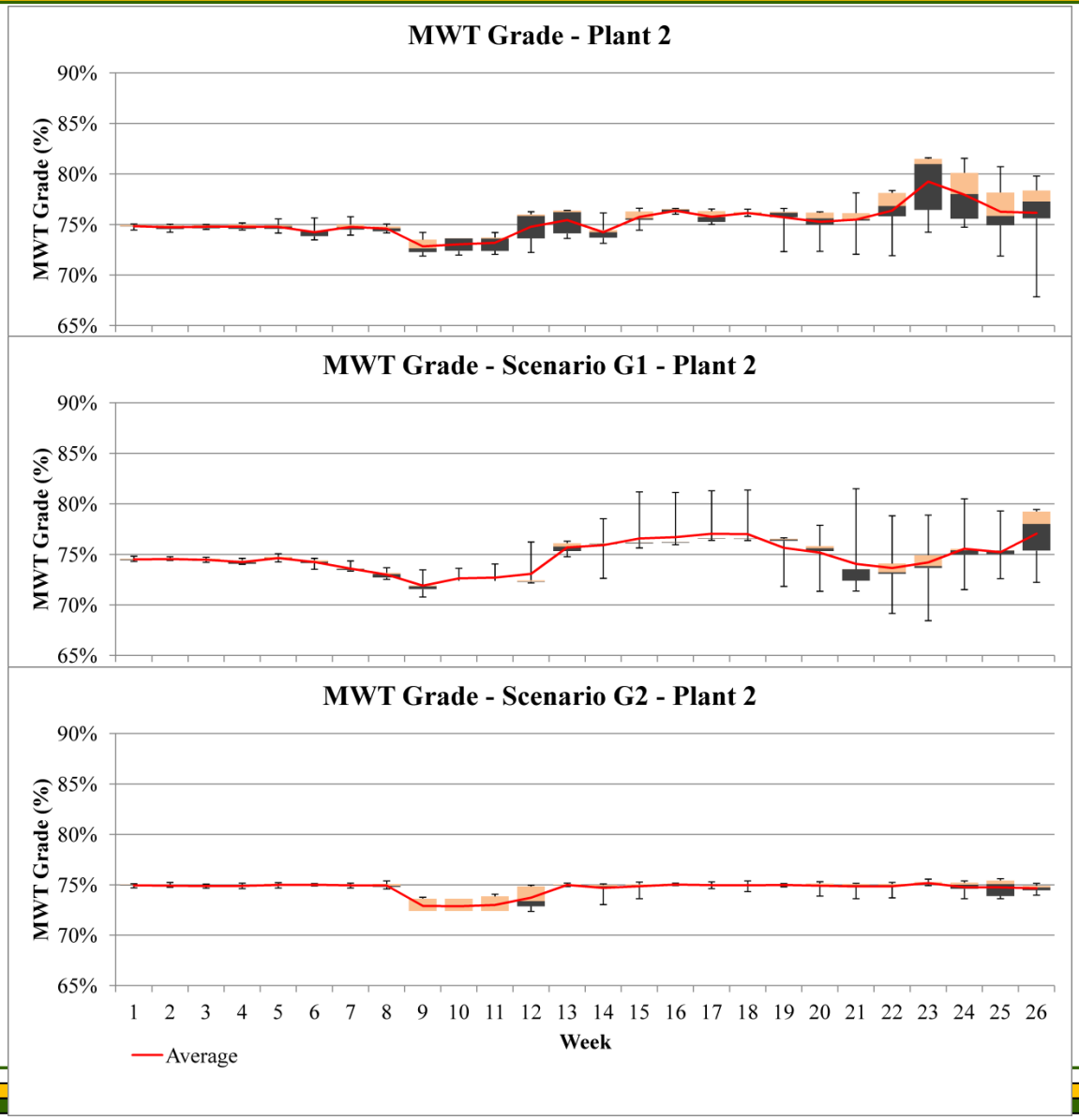



Base Case – Equal Priority to Plants

Priority to Plant 1

Priority to Plant 2

# Implementation – Grade blending

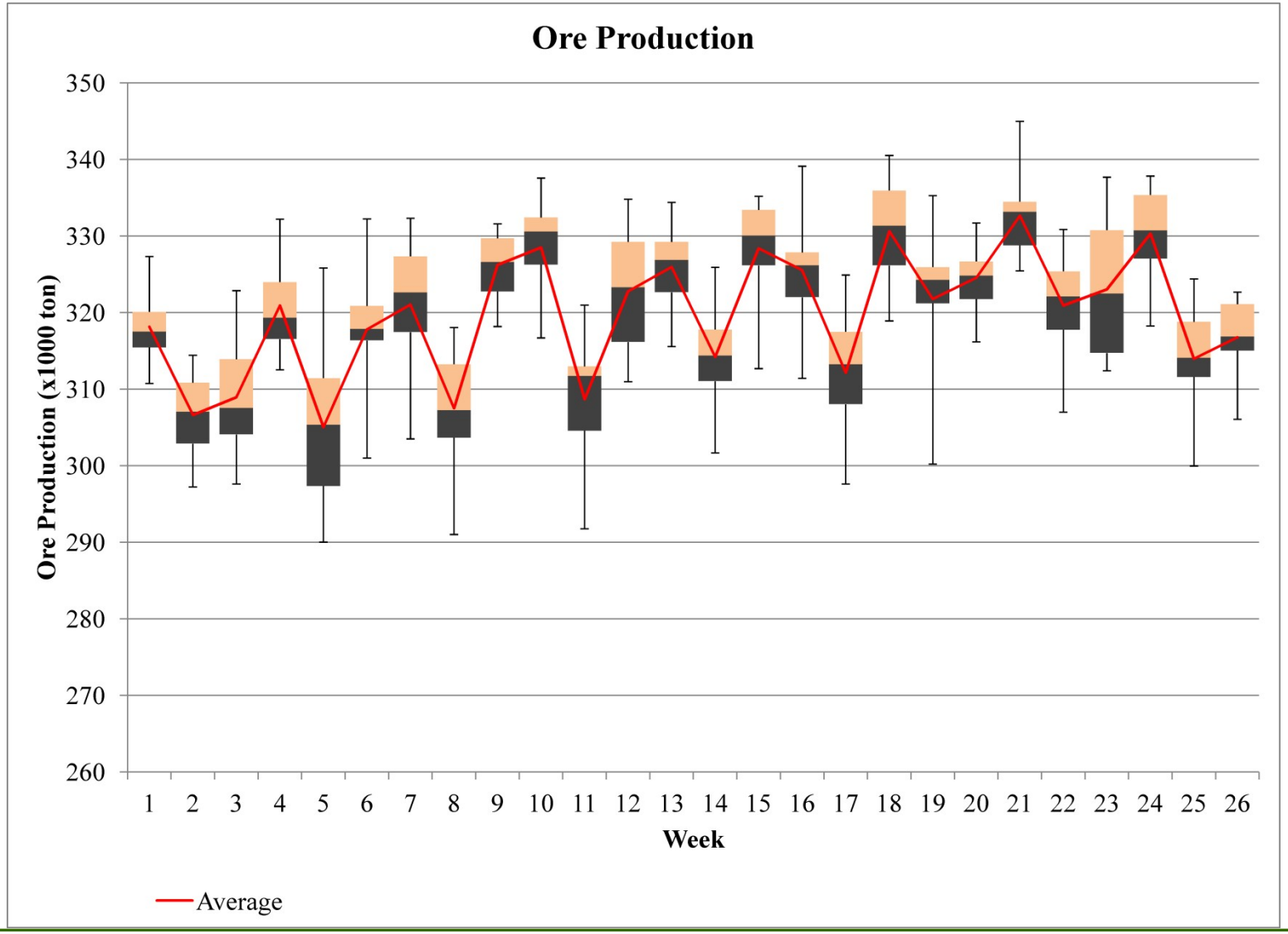



Base Case – Equal Priority to Plants

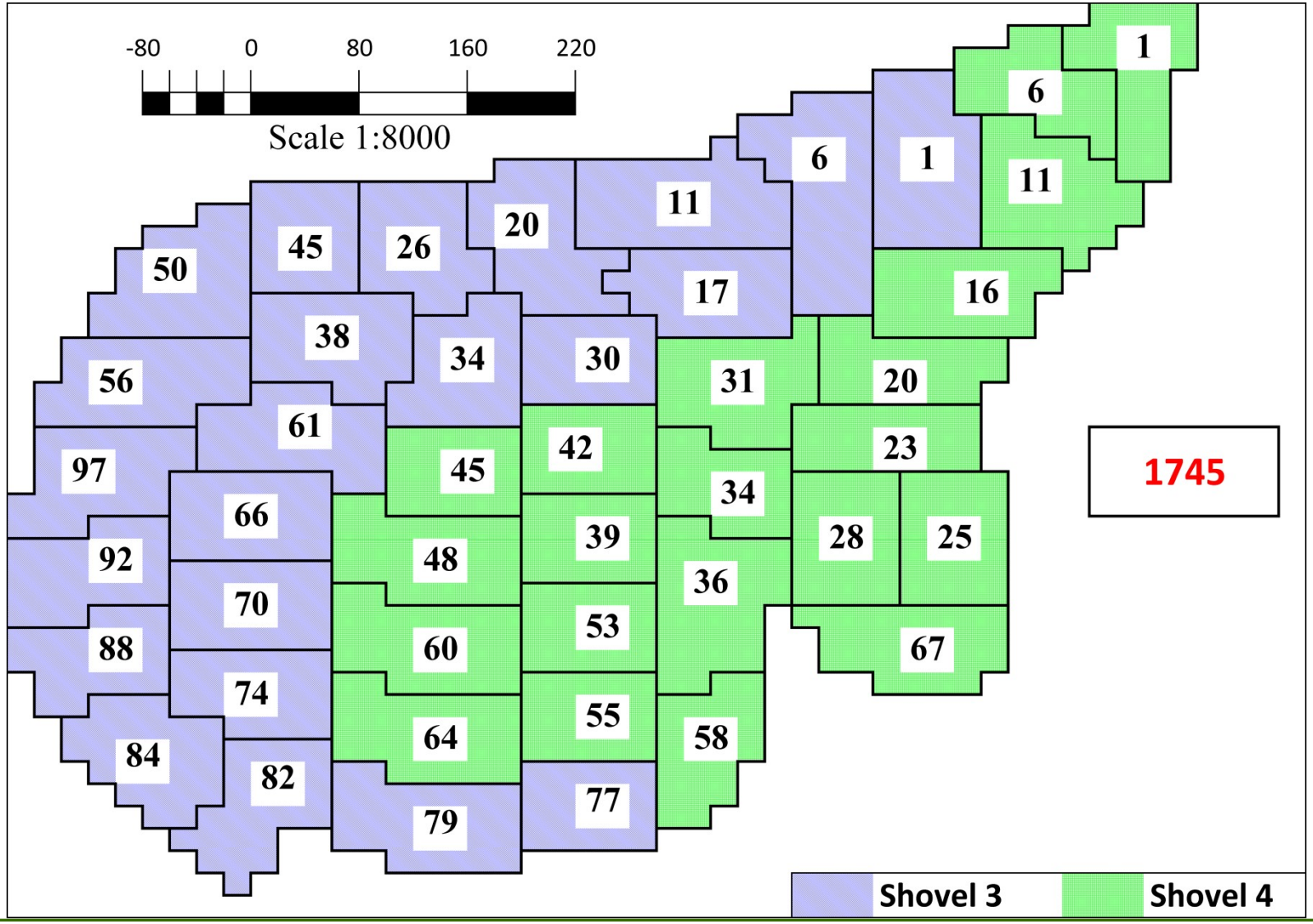
Priority to Plant 1

Priority to Plant 2

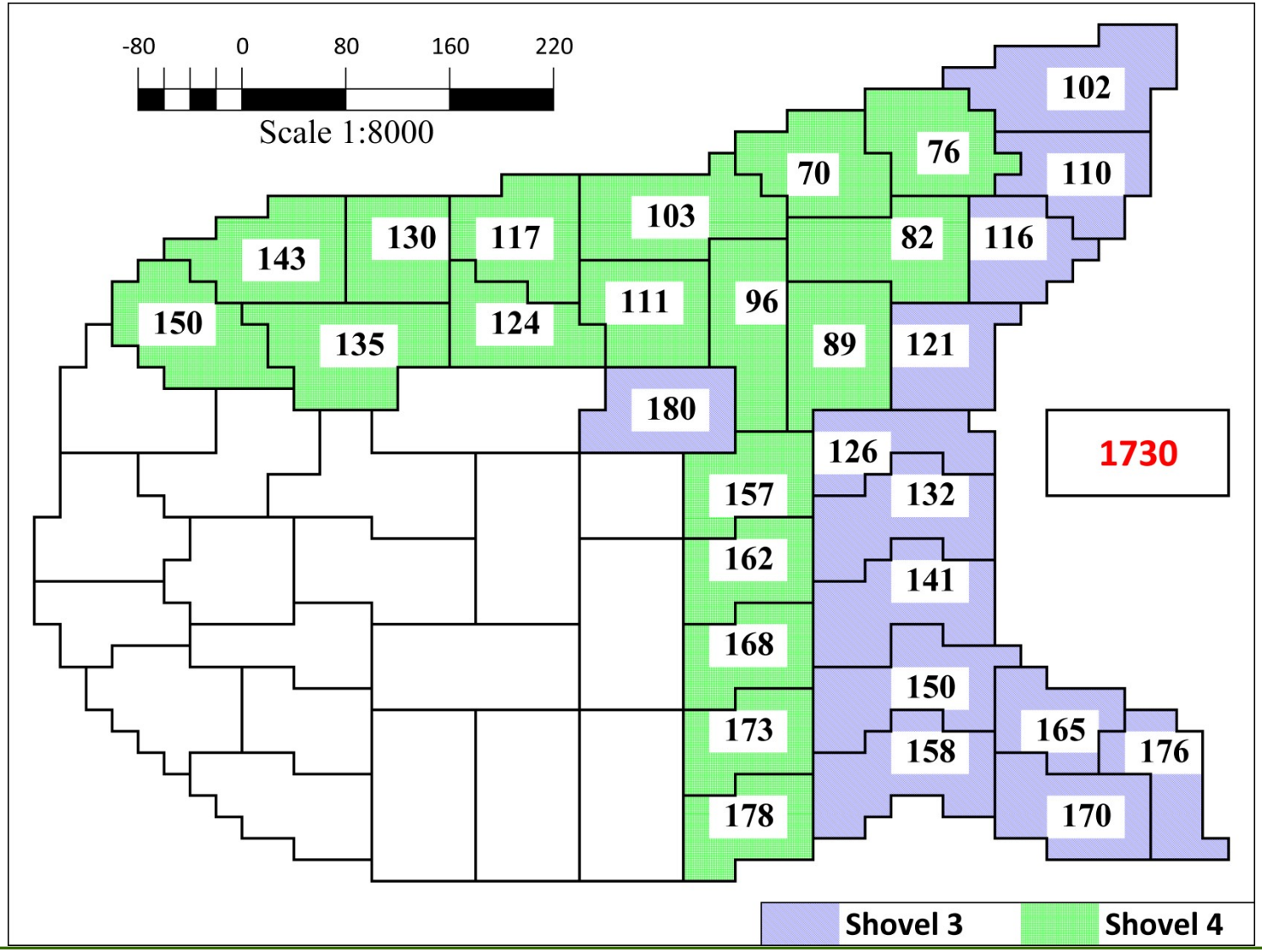
# Short term planning



# Results - Schedule



# Results - Schedule



# Thank You - Questions

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