Prescriptive Analytics & CPLEX Decision Optimization and TM1 Dashboard:
Combined Planning Power at JLG Industries

Megan L. Lillicrap – BI Analytics Manager
JLG Industries

Allie Barnes – BI Analyst
JLG Industries

Bruna Garcia – Consultant
QueBIT Consulting
Agenda

✓ Introductions and Company Overviews

✓ JLG Master Scheduling Solution Overview
  ▪ Problem Overview
  ▪ What is CPLEX?
  ▪ CPLEX & TM1 Integration
    ▪ Solution and Implementation

✓ Q&A
QueBIT Overview
Bruna Garcia – Consultant
About QueBIT

- Trusted Experts in Analytics
- **15+ years in business** with managers on the team who have been working in area of Analytics for 20+ years
- **Full Offerings** - Advisory & Implementation Services, Reseller of IBM Software and Developer of Solutions
- **900+** successful Analytics Projects
- **450+** analytics customers in all types of industries
- **100+ employees** with HQ in New York
- **Building an experienced team** from the ground up
- Deep Expertise in **Financial Analytics, Advanced Analytics, Business Intelligence, and DHW**
- Strong focus in **Financial Services** sector
- Multi-Year **Award Winner**
QueBIT: Trusted Experts in Analytics

We’re driven to help organizations improve their agility to make intelligent decisions that create value.

This is why we’re committed to excellence in analytics strategy and implementation.
JLG Industries Company Overview

Megan Lillicrap – BI Analytics Manager
Allie Barnes – BI Analyst

JLG
Oshkosh Corporation Company Overview

- Leading provider of specialty vehicles
- Nearly 100 years in business; incorporated in 1917

- Focused on delivering value to customers and shareholders
- Serial innovator of game-changing new products

[Forbes 2016 AMERICA'S BEST LARGE EMPLOYERS](https://www.forbes.com/bestemployers/)
[2016 WORLD'S MOST ETHICAL COMPANIES](https://www.ethisphere.com)
[APPROVED STEMJOBS EMPLOYERS 2016](https://www.stemjobs.com)
JLG Industries Company Overview

- Global headquarters in Hagerstown, MD
- Founded in 1969
- Global market leader in access equipment
- Global footprint:
  - 4 regional headquarters
  - 10 manufacturing facilities/4 continents
  - 19 sales and service centers
  - 4 parts distribution centers
  - 4 engineering centers
- Sales through 3,500+ customer locations on 6 continents
- Leader in towing and recovery
JLG Process Overview and Master Schedule Case Study
Megan Lillicrap – BI Analytics Manager
JLG Industries – JLG Process Overview

**Demand Forecast**
- Demand forecast driven by sales region

**Supply Planning**
- Sales, Inventory and Operation Planning (SIOP)
  - Balanced and constrained
  - Output is a supply plan by:
    - Product
    - Forecast Group
    - Month

**Master Schedule**
- Aligns SIOP Output and current Master Schedule
  - Updates production slots by:
    - Day
    - Product
    - Production facility
    - Assembly Line
    - Forecast Group
JLG Industries – Master Schedule Current State Overview

**Master Schedule**
- Updates take place in the ERP system manually.
- Production slots updated by:
  - Day
  - Product
  - Facility
  - Assembly line
  - Forecast group

**Material Requirements Planning (MRP)**
- MRP blows out the new production demand down to the individual component level.
- Creates the new supplier demand.

**Supplier PO Distribution**
- Based on MRP run, suppliers are cut new PO’s.
- Suppliers react to increased or decreased demand once requirements are communicated – typically 10+ days after SIOP is complete.
Planning takes place across:

- 35 Active Assembly Lines
- 220 Active Products
  - Committed Sales Orders
  - Exclusions
- 10 Forecast Groups
  - Priority Ordering
  - Default Forecast Group
- Periods
  - Up to 24 months

- Each month it takes 10 days to complete process – considered ‘admin’ work.*

* Data has been adjusted for presentation purposes.
JLG Industries – Master Schedule Business Problem

Current State

• Master schedule alignment to SIOP Plan takes roughly 10 days
  • Differences in planning bills for regional forecast are significant enough that until process is complete, supplier forecasts are misstated.
  • Due to material lead times, the MRP supplier forecast needs to be as accurate as possible, and updated quickly after each SIOP cycle.
  • Ultimately, limits suppliers ability to react and adjust to updated demand

Future State

• Reduce manual effort by the Master Scheduler
• More timely and accurate supplier forecast
• More timely and accurate financial analysis for projected spend and budgets
JLG Industries and QueBIT Partnership

- Previously partnered for initial Sales, Inventory and Operation Planning (SIOP) model - implemented in late 2016
- Continued relationship on the SIOP to Master Schedule project in 2017

- Core focus on:
  - Improving forecast accuracy
  - Streamlining and automating processes/manual work
  - Future scalability
  - Knowledge transfer
Onsite Detailed Requirements Gathering Session

- 1 week with core team
- Understand current state
- Design a recommended future state

- TM1
  - Models
  - Interfaces
- CPLEX
  - Logic
Objectives/Constraints for CPLEX Optimization Logic:
1. Cannot modify production slot that has a committed sales orders
2. Ignore/exclude products, production lines and months based on user input
3. Must meet production plan targets defined in the SIOP process
4. Priority weighting based on forecast groups (sales regions)
5. Level Loading by forecast group within a production line
What is CPLEX?
Bruna Garcia - Consultant
Optimization

• Definition:
  • The action of making the best or most effective use of a situation or resource

• Parts of an Optimization Problem
  • Decision Variables
  • Objective Function
  • Bounds
  • Constraints

• Examples of Optimization in Industry
  • Scheduling
  • Logistics
  • Pricing
What is CPLEX?

- Optimization Software Owned by IBM
  - Capabilities
    - ETL
    - Data cleansing
    - Optimization
      - Integer programming
      - Linear programming
      - Quadratic programming
  - Programming Language
    - Optimization Programming Language (OPL)
      - Proprietary language suited for optimization
      - Functions specific to types of optimization problems
Why TM1 + CPLEX?

TM1:

- Is a perfect home for optimization constraints
- Provides a user interface for CPLEX
- Can load results of CPLEX solution back into the models
- Can be used to version data
Why TM1 + CPLEX?

- CPLEX
  - Offers engine for optimization that TM1 can leverage
  - Reads from csv files, which are easily output by TM1
  - Data structures needed for solutions are similarly formatted to the way TM1 already holds data
Why TM1 + CPLEX?
- Together
  - Input constraints into TM1
  - Press button to run solution
  - See updated results in TM1
CPLEX – TM1 Integration

• Issues:
  • IBM Connector
    • Cannot connect if TM1 and CPLEX on different servers
      • Both memory intensive
      • Licensed based on PVU
    • IBM is working on adding cross-server functionality in the future
      • Robust solution if working properly
    • Integration of CPLEX on the cloud
  • TM1 Command Function
    • CPLEX is unable read from excel files if called from TM1 directly or through a batch file called by TM1
TM1 & CPLEX Integration

**Data Extracts**
- TM1 – generates data extracts to push to CPLEX

**Batch File**
- TM1 – Calls CPLEX through a batch file; executed through Task Scheduler

**CPLEX Optimizes**
- Based on data & constraints fed to the model from TM1

**Flag Files**
- Optimized results are produced, flag file is created

**Load Processes**
- TM1 detects flag file – initiates load processes to create separate versions
Setting the Stage in CPLEX with TM1
Allie Barnes – BI Analyst
Setting the Stage in CPLEX with TM1

• Collecting user input in TM1 to control the process
• CPLEX $\rightarrow$ Hard Coding within model; TM1 $\rightarrow$ User interface
• CPLEX constraints are directly fed from TM1
Set the starting date for optimization by manufacturing line

**Forecast Allocation Start Month Input Template**

**FUNCTIONALITY**
- After the SIOP month is changed, run the "Update Default Month"
- If a start allocation month needs to be changed:
  - Step 1: Clear out the value in the default start month
  - Step 2: Place a "1" in the appropriate month and click "Update"
  - Step 3: This will spread the allocation month to all products and all forecast groups for the given line

<table>
<thead>
<tr>
<th>MS ASSUMPTION</th>
<th>Forecast Allocation Start</th>
<th>Update Default Month</th>
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<tbody>
<tr>
<td>CURRENT FORECAST PERIOD</td>
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</tr>
</tbody>
</table>

* Data has been adjusted for presentation purposes.
Number of Workdays Input Template

- Set number of workdays by manufacturing lines
- CPLEX uses number of workdays to determine the number of manufacturing slots available for allocation

Example: Line shut down for maintenance purposes. Working days reduced. CPLEX will reduce amount of slots to reallocate.

* Data has been adjusted for presentation purposes.
Forecast Group Assumptions Input Templates

- Set order by which sales regions (forecast groups) will absorb any schedule discrepancies by manufacturing line.

- Users can control the sales regions priority to influence who receives shortages or excess of products.

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Objectives/Constraints Master Schedule Logic:
1. Cannot modify production slot that has a committed sales orders
2. Ignore/exclude products, production lines and months based on user input
3. Must meet production plan targets defined in the SIOP process
4. Priority weighting based on forecast groups (sales regions)
5. Level Loading by forecast group within a production line
# CPLEX Optimization – Scenario 1

**Master Schedule Adjustments Input Template**

**FUNCTIONALITY:**
1. Refresh Product List based on selected Warehouse Line > Click "Update Product List" Button
2. Click "Send/Refresh Data" Button to Refresh data for Selected Warehouse Line - Product Code
3. Input Adjustments to Delta Override Measure and click "Send/Refresh Data" Button
4. Click "Run CPLEX Round Trip" button to initiate CPLEX and load optimized Results
5. When MS is finalized, Click "Send Data to iSeries" Button
   - Adjusted MS is the SUM of Effective Delta and Master Schedule

---

## SET PARAMETERS:

<table>
<thead>
<tr>
<th>PRODUCTION WAREHOUSE-LINE:</th>
<th>32-32- E600/600A LINE (SHP)</th>
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<tbody>
<tr>
<td>PRODUCT:</td>
<td>19B-600A PFP</td>
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<td>START PERIOD:</td>
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<td>SIOP PLAN VERSION:</td>
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<td>CPLEX RUN DETAILS:</td>
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<td>CPLEX STATUS:</td>
<td>32-32- E600/600A LINE (SHP): Run Successful</td>
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<td>COMPLETION FILE DETAILS:</td>
<td>Assignments: 2258, Warnings: 2, Errors: 0</td>
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## LOAD MASTER SCHEDULE

## SEND/REFRESH DATA

---

## Jul 17

<table>
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<tr>
<th>Master Schedule Working Version</th>
<th>Optimized Version</th>
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<td>Effective Delta</td>
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<td>Delta Override</td>
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<td>Adjusted MS</td>
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<tr>
<td>Effective Delta</td>
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| NORTH AMERICA | 128 | 74 | 54 | 128 | - | - | 128 | - |
| PAC RIM       | -   | -  | -  | -   | - | - | - | - |
| LATIN AMERICA | 9   | 9  | 9  | 9   | - | - | 9  | - |
| EQUIPMENT SERVICES | -   | -  | -  | -   | - | - | - | - |
| EUROPE        | 17  | 3  | 14 | 17  | - | - | 17 | - |
| AUSTRALIA     | -   | -  | -  | -   | - | - | - | - |
| CHINA         | -   | -  | -  | -   | - | - | - | - |
| BRAZIL        | -   | -  | -  | -   | - | - | - | - |
| AFRICA & MIDDLE EAST | 2   | 1  | 1  | 2   | - | - | 2  | - |
| ENGINEERING   | -   | -  | -  | -   | - | - | - | - |

## Aug 17

<table>
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<th>Master Schedule Working Version</th>
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<td>Adjusted MS</td>
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<tr>
<td>Effective Delta</td>
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| NORTH AMERICA | 137 | 29 | 108 | 137 | - | - | 137 | - |
| PAC RIM       | -   | -  | -  | -   | - | - | - | - |
| LATIN AMERICA | 116 | 26 | 85  | 111 | (5) | - | 111 | - |
| EQUIPMENT SERVICES | -   | -  | -  | -   | - | - | - | - |
| EUROPE        | 13  | 3  | 15 | 18  | 5 | - | 18 | - |
| AUSTRALIA     | -   | -  | -  | -   | - | - | - | - |
| CHINA         | -   | -  | -  | -   | - | - | - | - |
| BRAZIL        | -   | -  | -  | -   | - | - | - | - |
| AFRICA & MIDDLE EAST | 4   | 6  | 6  | 2   | - | 6 | - | - |
| ENGINEERING   | -   | -  | -  | -   | - | - | - | - |

* Data has been adjusted for presentation purposes.
Must meet production plan targets defined in the SIOP process

Priority weighting based on forecast groups

* Data has been adjusted for presentation purposes.
CPLEX Optimization – Scenario 2

Master Schedule Adjustments Input Template

FUNCTIONALITY:
1. Refresh Product List based on selected Warehouse-Line > Click "Update Product List" Button
2. Click "Send/Refresh Data" Button to refresh data for Selected Warehouse-Line - Product Code
3. Input Adjustments to Delta Override Measure and click "Send/Refresh Data" Button
4. Click "Run CPLEX Round Trip" button to initiate CPLEX and load optimized Results
5. When MS is finalized, Click "Send Data to Series" Button
* Adjusted MS is the SUM of Effective Delta and Master Schedule

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**CPLEX Optimization – Scenario 2**

**Cannot modify** production slots that have committed sales orders

**Must meet** production plan targets defined in the SIOP process

**Priority weighting** based on forecast groups

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JLG Master Schedule Solution Implementation
Allie Barnes – BI Analyst
Lessons Learned – Improvement Opportunities

• General TM1 Governance
  • Followed up with a project to target TM1 Governance

• CPLEX – TM1 Connector
  • Not useful in a practical environment

• Batch Files
  • Multiple issues caused by background processes between the two products
  • Can be worked around through a scheduled task
Lessons Learned – What Went Right

• Testing
  • Proof of Concept for CPLEX
  • Unit, Functional and User Acceptance Testing

• Multiple Weekly Touchpoints
  • Technical meetings (IT team)
  • Business review meetings (Core team)

• Knowledge Transfer
  • Built in time within our Project Schedule for shadowing development with QueBIT
  • Peer reviews

• CPLEX – TM1 Partnership
Solution Results

• Successful implementation at JLG
• Reduced manual effort: 10 days to 3 days / month
  • Estimated $70K saved annually
  • Allows time for more strategic work versus admin work

• Future Measures of Savings
  • More timely and accurate supplier forecast
    • Estimated $250K savings annually
    • Less expediting and shortages associated with inaccurate forecasts
  • More timely and accurate financial analysis for projected spend and budgets
    • Estimated $20K savings annually
**JLG Industries – Master Schedule Future State Process Flow**

**Master Schedule**
- Updates are pushed from TM1 to ERP system by the click of a button.
  - Production slots updated by:
    - Day
    - Product
    - Facility
    - Assembly line
    - Forecast group

**Material Requirements Planning (MRP)**
- MRP blows out the new production demand down to the individual component level required.
  - Creates the new supplier demand.

**Supplier PO Distribution**
- Based on MRP run, suppliers are cut new PO’s.
  - Suppliers now react to increased or decreased demand ONE WEEK sooner.
“12 minutes from the time I opened TM1 for production line 22 until I got the e-mail confirmation that updates were made to the master schedule.

This process just allocated roughly 1,000 production slots to the appropriate forecast groups from June 2017 through September 2018 in 12 minutes, which included time to review data to make sure there were no issues.

Thank you to everyone for their help. This is what I call a win!”

- Bruce DeMaster, Value Stream Manager

* Data has been adjusted for presentation purposes.
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Q&A

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Allie Barnes
Bruna Garcia

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Vision
2017
Thank you!

Vision 2017