Digitalization of Packing and Loading in Supply Chain Operations


Nelson Capote


Xindi Liu


Udyog Pati


Tommy Starnes

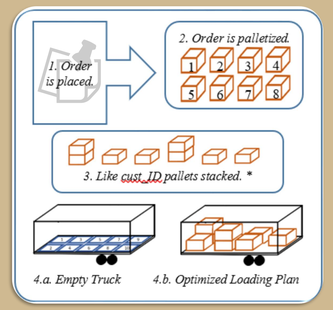
Matthew A. Lanham
Purdue University, Mitch Daniels School of Business
ncapote@purdue.edu; liu3507@purdue.edu; upati@purdue.edu; tstarn00@purdue.edu; lanhamm@purdue.edu

BUSINESS PROBLEM FRAMING

Given an order of multiple items, we are predicting the number of pallets required to transport the order and optimizing the **spatial utilization** within a transportation asset. We strive to **minimize** wasted space and time in the packing of the trucks. It is done through a **predictive** & **optimization** model. Constraints faced are limitations on space available within the truck, stacking of pallets limited to specific materials, and maximum weight of the pallet. Once able to employ the model, the client is able to more rapidly predict, plan, package, and load orders, mitigating delays in delivery.

INTRODUCTION

The Taguchi Loss Function explains how the further the deliverable deviates from what is acceptable, the overall loss to the company grows exponentially. Smooth and orderly packaging, **stacking**, and **loading** of goods onto delivery trucks is vital to a successful supply chain. Putting these two statements together it is apparent that any proactive approach to maximizing efficiency and optimizing the supply chain operations must be taken.



RESEARCH OBJECTIVES

- Existing packing optimization models
  - MCLP (Multi-Container Loading Problem)
  - LAFF (Largest Area Fit First)
- Genetic Algorithm
- Deterministic model (Optimization)

ANALYTICS PROBLEM FRAMING

Our prediction and optimization model revolve around two key components: 1) a given order of items funneled through 2) constraints. Our constraints are a combination of 1) pre-determined constraints on size, weight, and stackable materials, and 2) user-defined constraints such as the availability of different models of delivery trucks.

We safely assume not all orders will require a completely packaged pallet, thus giving us either “partial pallets” or excess items secured to the top of an existing pallet (Image 1). We also assume that if two pallets can be/are stacked, they are of the same or like materials (Image 2). They must be of the same material.

In order to deliver a pure, optimized loading plan for our client, we must embrace the constraints. The subjective fog that birthed this problem is an over-reliance on experience in warehouse operations and the packaging, stacking, and loading of orders. Our constraints are designed to encompass and qualify pre-existing notions and experience into the stacking and loading of pallets.

Image 1

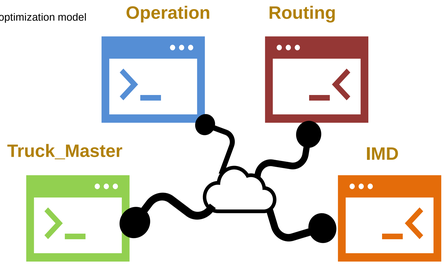
Image 2

Image 3

DATA

- Multiple tables received joined together on primary key to create master dataset. Each table contained segments of the final constraints for optimization model.
  - Item_Master_Data(IMD): Provides the distinguishing item number, **weight**, **length, width, height,** and description.
  - Truck Master: Provides the list of trucks within the client’s fleet. This provides **length, width,** and **height** of the box which items are placed. This list also provides information regarding the truck’s **max** Allowable Cargo Load (ACL).
  - Operation: Comprised of an order list for the entire month of Feb. 2023. It provides information on the item number, quantity of items ordered by item number, **weight**, pieces per crate, **Order_ID**, and **Customer_ID.**
  - Routing: Provide order information for each truck route.
- Constraints within the table enable model development to support the business problem of predicting the number of pallets required to ship an order (Routing, IMD and Operation Table), the number of pallets a truck can ship (Truck Master), the stacking and grouping of pallets for a single order (Order_ID and Customer_ID), and stackable pallets (IMD).

*Bold items refer to information used in constraints within optimization model



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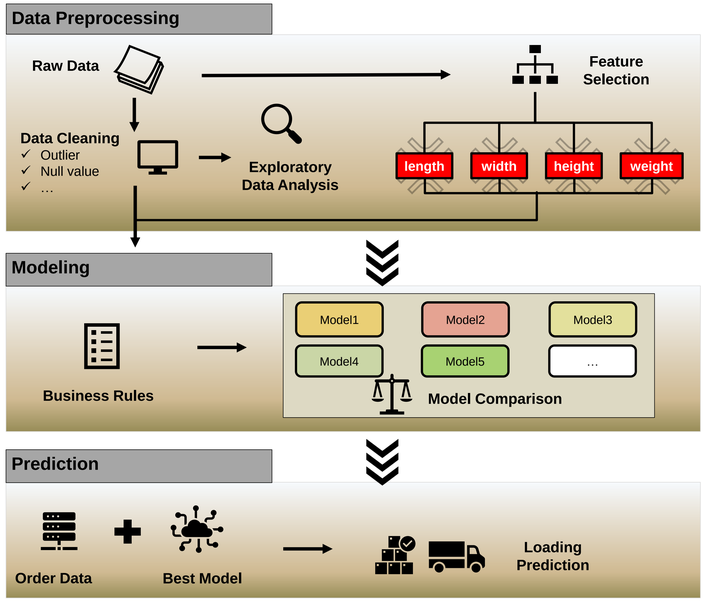
METHODOLOGY



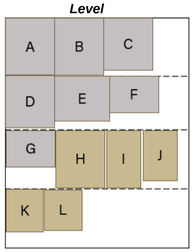
MODEL BUILDING

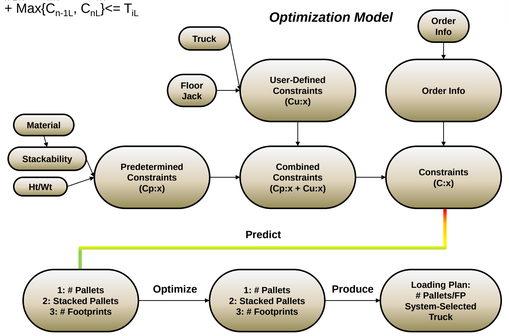
Our approach was programmed in Python. Two algorithms were created: Level algorithm and Optimization Model algorithm. We took into consideration on both container and item dimensions. The detail model structure is showed as below.

(T_L, T_W, T_H, T_{WT}) : Length, Width, Height, Weight of Trucks; i presents index for truck types
(C_L, C_W, C_H, C_{WT}): Length, Width, Height, Weight of Crates; j presents index for crates

Constraints:

Max {$(C_{1W} + C_{2W})$, $(C_{2W} + C_{4W})$, …, $(C_{n\text{-}1W} + C_{nW})$} <= T_{iW}
Max {C_{1L}, C_{2L}} + Max {C_{3L}, C_{4L}} + … + Max{$C_{n\text{-}1L}$, C_{nL}}<= T_{iL}
Max{$\sum_{j=1}^{k} C_{jH}$}<= T_{iH}
$\sum_{j=1}^{n} C_{jWT}$ <= T_{iWT}





DEPLOYMENT & LIFE CYCLE MANAGEMENT

Business Solution Demonstration

Loading Estimate by Truck

Type (Truck)	Area Unused	Weight Unused	# of Pallets Loaded	# of Stacked Pallets	# Partial Base
29'	4107.7	4	13	10	-
29'	642.7	6786	9	4	1
26'	3559.5	12496	9	1	2

Upon implementation, the company can predict how many pallets are required to fill an order and whether all the pallets can be stacked effectively.

Additionally, the optimization model is proving support making the loading of pallets on trucks leaner.

Future Scope of Project

Immediate and continued feedback on the model enables it to grow and improve prediction power.

Tending to the Master Order List and database to clean erroneous dimensional and weight data will enable the model to perform more effectively.

If the company could record the financial loss to the business on how the loading of delivery trucks were handled prior to implementation of our model, we could objectively measure how our model help to improve the company’s operations efficiency and cost saving.

CONCLUSIONS

The model has proven to improve the accuracy in predicting the number of pallets required and footprint utilization of pallets. Previously estimated pallet quantities and space utilization on delivery trucks have been replaced with this prediction and optimization model which removed the guess-work in the warehouse.

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