Streamlining Doosan Bobcat's Sales Portfolio Using Mixed-Integer Optimization

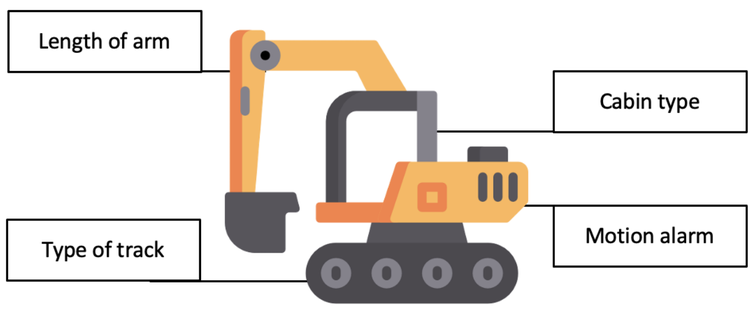
MBAn Team: Benedict Lee and Aritro Nandi
Faculty Advisor: Dr Bart Van Parys
Supervisor: Tomas Pribyl

1. Introduction

Being one of the largest companies in the construction equipment manufacturing sector, Doosan Bobcat handles a massive number of orders yearly from all over the world. Over the course of the beginning of the pandemic, the company, like many others, faced a shortage of orders. This past year has seen many customers return to their prior levels of demand, resulting in a surge of orders.

The 2021 surge of orders from returning customers has resulted in the company having to reconsider the process by which Bobcats are manufactured in the EMEA region, specifically in the level of customization that the customer has for each order. Each Bobcat offers different options, such as LED lights, heating, radio, etc. Each order can have **up to 7000+ different options**.

2. Project Objective



The great variety of options available adds to the manufacturing time and makes it more difficult to alleviate the current backlog of orders.

The objective of this project is to propose a portfolio of sales packages that **improves procurement and supply chain operations, streamlines sales, and increases profits**.

3. Datasets and Tools

Datasets provided:

1. Order transaction data from 2021
2. Financial information for each option

Tools used:

1. Python and pandas/NumPy
2. Julia and JuMP

4. Approach I: Descriptive Analytics

We prepared a consolidated file for key decision makers. The final consolidated file contained data such as the **take-rate, list price, and cost of each option**, and heuristic metrics such as specification rating and regional volatility.

For the E19 model, four packages were created in consultation with the product manager, who had **extensive domain knowledge**.

5. Approach II: Mixed-Integer Optimization

Optimization Formulation

Decision Variables

- $X_{ijk} \geq 0$: number of people in package k who choose option ij
- $Y_{kl} \in \{0,1\}$: binary - whether customer l is in package k
- $Z_{ijk} \in \{0,1\}$: binary - whether option ij is in package k

Objective Function

$$\max \quad \sum_{i=1}^{v}\sum_{j=1}^{m}\left(\sum_{k=1}^{q} X_{ijk}\right) * (P-c)_{ij}$$

Constraints

1. Each customer can be assigned to at most 1 package:

$$\sum_{k=1}^{q} Y_{kl} \leq 1 \; \forall \, l = 1, \ldots, r$$

2. Each package contains only one C option in each R subgroup::

$$\sum_{j=1}^{m} Z_{ijk} = 1 \; \forall \, i = 1, \ldots, v; k = 1, \ldots, q$$

3. $X_{ijk} = 0$ if $Z_{ijk} = 0$ and it is unconstrained otherwise

$$X_{ijk} \leq M * Z_{ijk} \forall \, i, j, k$$

4. Y and X have the same number of customers for each package

$$\sum_{l=1}^{r} Y_{kl} = \sum_{i=1}^{v}\sum_{j=1}^{m} X_{ijk} \forall \, k = 1, \ldots, q$$

5. The new price of the package must be less than a p_thresh * 100% markup of the original price the customer paid, where p_thresh is a hyperparameter that can be any number between 0 and 1

$$M' * (1 - Y_{kl}) \geq \sum_{i=1}^{v}\sum_{j=1}^{m} P_{ij} * Z_{ijk} - (1 + \text{p\_thresh}) * \text{order\_prices}_l \; \forall \, k = 1, \ldots, q; l = 1, \ldots, r$$

6. The spec rating of the options in each package should be above s_thresh * 100% of the spec rating of the original order by the customer, where s_thresh is a hyperparameter that can be any number between 0 and 1

$$N * (1 - Y_{kl}) \geq (\text{s\_thresh} * \text{order\_specs}_l) - \sum_{i=1}^{v}\sum_{j=1}^{m} s_{ij} * Z_{ijk} \forall \, k = 1, \ldots, q; l = 1, \ldots, r$$

7. The only options that are allowed to have customers or packages assigned to them are legal options

$$X_{ijk} \leq Q * a_{ij} \forall \, i = 1, \ldots, v; j = 1, \ldots, m; k = 1, \ldots, q$$

$$Z_{ijk} \leq Q * a_{ij} \forall \, i = 1, \ldots, v; j = 1, \ldots, m; k = 1, \ldots, q$$

Business Impact

1. Packages created by the MIO are projected to lead to a **67% reduction** in the number of options on average, resulting in a decrease in complexity and labor costs

2. The MIO code is **highly customizable**, and any additional constraints in the future can be easily added to the MIO

3. Using both Approach I (qualitative) and Approach II (quantitative) allows product managers and the supply chain team to derive optimal packages that **suit customers' needs**

Results