IE3100M SYSTEMS DESIGN PROJECT AY19/20
Department of Industrial Systems Engineering and Management

LOAD LINER OPTIMISATION

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PROBLEM

PIL's current cargo allocation process is manually calculated by their trade managers. It is **time consuming, error prone and non-optimal** which affects the company's profit.

OBJECTIVE

To create a program to **recommend an optimal allocation** for 20'/40' cargo containers to yield the **highest contribution margin** for a specific described shipping line.

METHODOLOGY

Requirements
Understand constraints and pain points faced by the trade managers

System Analysis
Study the specifications and conceptualise suitable optimisation methods

Design
Formulate mathematical algorithm and test using Excel

Implementation
Produce the actual code required for the model using Python

Testing
Perform stress test and gather feedbacks for improvement

Integration
Full integration of Python into PIL's system for all users

PROTOTYPE

STEP 1:

Decided to test on West Coast Central and America 2

- It is one of the **most complex** shipping routes
- It has one of the **most port-pairs**
- It has **move count** and **draft restriction** as constraints

STEP 2:

Formulated objective function and constraints

In WS2, the mathematical formulation is shown below:

$$\text{Max.} \sum_{k=1}^{4}\sum^{|V|}\sum_{i=1}^{5}\sum_{j=1}^{5} C^k_{hij} X^k_{hij}$$

s.t.

Physical Constraints:

$$\sum_{k=1}^{2}\sum^{|V|}\sum_{i=1}^{5}\sum_{j=1}^{5} X^k_{hij} + 2\sum_{k=3}^{4}\sum^{|V|}\sum_{i=1}^{5}\sum_{j=1}^{5} X^k_{hij} \le U$$

$$\sum_{k=1}^{4}\sum^{|V|}\sum_{i=1}^{5}\sum_{j=1}^{5} W^k_{hij} X^k_{hij} \le Z$$

$$\sum_{k=1}^{4}\sum^{|V|}\sum_{i=1}^{5} X^k_{hi4} \le 311\ Moves$$

$$\sum_{k=1}^{4}\sum^{|V|}\sum_{i=1}^{5}\sum_{j=4}^{5} W^k_{hij} X^k_{hij} \le 11224\ Tons$$

$$\sum_{k=1}^{4}\sum^{|V|}\sum_{i=1}^{5}\sum_{j=5}^{5} W^k_{hij} X^k_{hij} \le 5946\ Tons$$

Business Constraints:

$$l^k_{hij} \le X^k_{hij} \le U^k_{hij} \qquad \forall i \in L, j \in D, h \in V, k \in E$$

$$\sum_{k=1}^{2}\sum^{|V|}\sum_{j=1}^{5} X^k_{hij} + 2\sum_{k=3}^{4}\sum^{|V|}\sum_{j=1}^{5} X^k_{ij} \ge T_i \quad \forall i \in L$$

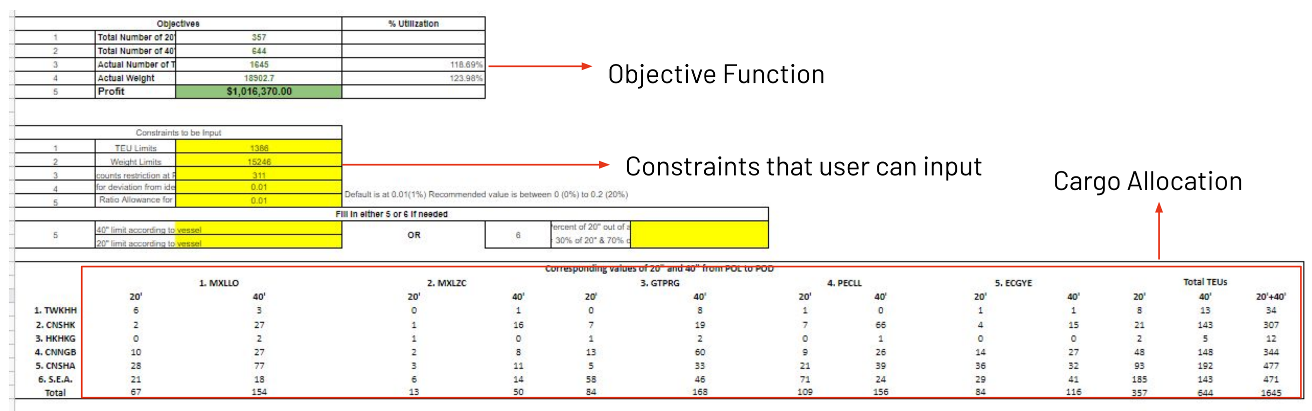
$$\sum_{k=1}^{2}\sum^{|V|}\sum_{i=1}^{5} X^k_{hij} + 2\sum_{k=3}^{4}\sum^{|V|}\sum_{i=1}^{5} X^k_{hij} \ge T_j \qquad \forall j \in D \ (2\text{-}9)$$

$$X^k_{hij} \ge 0 \text{ and integer} \qquad \forall i \in L, j \in D, k \in E$$

- ✓ Maximise the objective function: **Sum of total contribution margin** from each container in the optimum allocation.
- ✓ Objective function subject to **physical constraints** such as **draft restrictions, weight limit and capacity limit**.
- ✓ Objective function subject to **business constraints** such as **minimum and maximum no. of containers** from certain ports.

STEP 3:

Created a **prototype model** for testing



STEP 4:

Compared results from model with historical allocation of WS2,

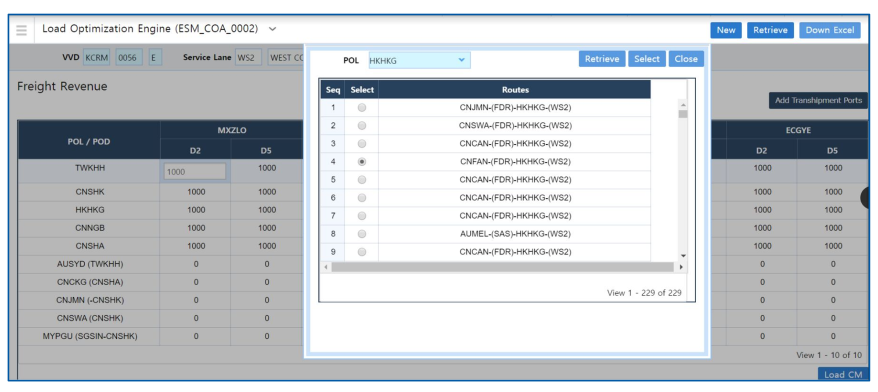
+$110,348.50	**$736,448.25**	**16%**
Increase in Profit	Profit from Model	Percentage of Change in Profit

IMPLEMENTATION

Coding the Application

PuLP package is used to **formulate and solve the integer program in Python**. PuLP uses the **Coin-or Branch and Cut (CBC) solver**, which uses a branch-bound and cut method to solve IP problems.

The frontend interface, hosted on PIL's LMS platform, and the optimisation engine communicate via **JSON outputs**.



Designing User Interface

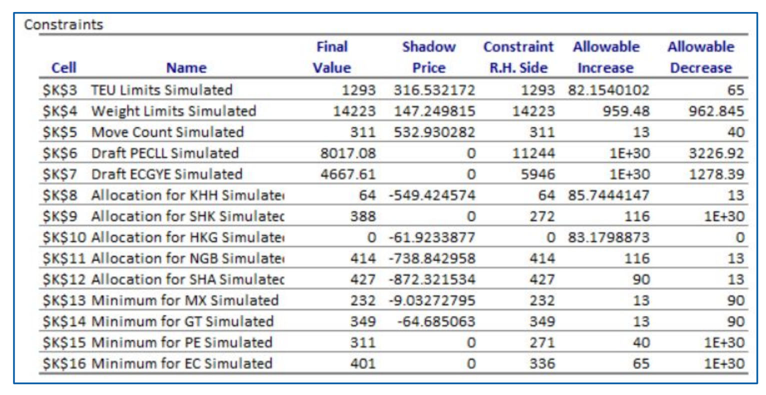
After evaluating requirements from end users, the team designed an interface that is simple and user friendly. It will **automatically fill** in key data of a chosen vessel and shipping route.

It also **allows users to update important details** and constraints if required.

Final Integration

The team **successfully created a model** that gives the optimum allocation for different vessels and all shipping routes.

The application was **successfully integrated into PIL's Liner Management System.** All trade managers can use this application.



Sensitivity Analysis

The team also **performed sensitivity analysis** to identify the effect of a small change in a constraint on the objective function.

Users will be able to **identify the impact** that a constraint has on the contribution margin using its **shadow price**.

ACHIEVEMENTS & BENEFITS

✓ Impacts

- Instantly gives optimum allocation, **saving time**
- **Reduced errors** in allocation
- **Increase revenue** for all shipping trade routes

Model Outcome

Projected Profits Across All Routes Using The Model

Increase in Profits

$4,981,060.00

Percentage Increase in Profit

+10%

✓ Benefits of Model

- **Ease of Use**
- **Scalable** for future service lines
- **Highly accessible**

FUTURE DIRECTION

- **Calculating profit** in addition to contribution margin by fixing cost
- **Incorporating simulation models** to reduce waiting time for ports
- **Interconnecting different services** for more comprehensive solution
- **Employing Machine Learning** to forecast demand and supply for portpair constraints.

KEY SKILLS

Soft Skills

+ Project Management
Used Gantt Chart and Waterfall methodology

+ Consulting
Understood user pain points and challenges

Technical Skills

+ Programming
Coded program in Python language

+ Operation Research
Applied Integer Linear Programming concepts

+ Process Improvement
Automated complex calculation and reduced human error

+ Data Analysis & Visualisation
Performed sensitivity analysis, Created interface to display results