Department of Industrial Systems Engineering and Management
IE3100M Systems Design Project

FORECASTING JURONG PORT'S CEMENT THROUGHPUT

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INTRODUCTION

PROBLEM STATEMENT

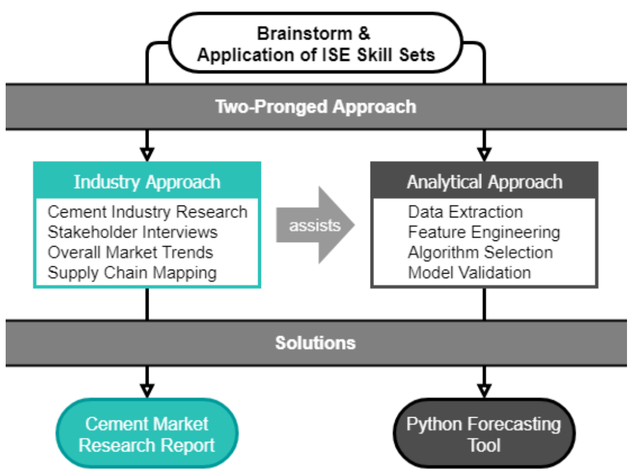
95% of Singapore inbound cement are discharged at Jurong Port, hence it is critical that Jurong Port has the required capacity to accommodate cement imports going forward. In order to anticipate future capacity constraints in Jurong Port, it is essential to forecast when the throughput will exceed threshold capacity, giving Jurong Port ample time to build the additional infrastructure to handle the increased levels. In addition, Jurong Port has requested for a validation of its own understanding of the cement industry.

AIM OF PROJECT

(1) Construct a **forecasting model** to predict cement throughput up to a period of 3 years in the future to aid in port capacity planning
(2) Produce a **cement market research report** consolidating the knowledge and findings from the interviews conducted

METHODOLOGY

TWO-PRONGED APPROACH



PREDICTIVE MODELLING PROCESS

Gaining Industry Understanding	• Interviews with industry stakeholders and NUS Civil Engineering professors • Online research
Data Collection	• Data was extracted from BCA Construction Infonet, data.gov.sg and Jurong Port
Features Engineering	• Possible features can be derived from major factors affecting cement industry discussed in Industry Approach • Preliminary analysis of the features • Fitting the different features into the machine learning models for further analysis
Model Development	• Design and analysis of different machine learning models • Selection of models based on different performance metrics
Cement Throughput Prediction	• Projection of features to predict future cement throughput either via combination of qualitative and quantitative approach

KEY SKILL SETS

Programming · Systems Thinking · Statistical Learning · Machine Learning · Market Research

EXPECTATIONS

Regenerative Design
Allows the forecasting tool to be used in the foreseeable future

Yearly Prediction
More useful instead of monthly predictions

Clear Box Model
Understand all internal prediction logic

INDUSTRY APPROACH

UNDERSTANDING CEMENT INDUSTRY

Aims to gain domain knowledge by interviewing industry stakeholders for Jurong Port to understand the cement industry. Valuable insights will be incorporated into the Analytical approach as features and validation of model.

Methods to estimate amount of Cement needed for different types of project

Method 1: HDB

Average tonnage of cement per dwelling unit = 0.5/m²

Amount of Cement Needed for one HDB Block
$= No.dwelling\ units \times Avg\ floor\ area/dwelling\ unit \times 0.5$

Amount of cement dependent on location

Method 2: MK Tunnel Pte. Ltd.

Assuming floor area is the same for every floor;
Floor & Ceiling Thickness = 0.5m

Amount of Concrete needed for one building
$= No.floors \times (Floor\ area \times Floor\&Ceiling\ Thickness + Vol.walls\ in\ 1\ unit \times No.units/floor)$

Amount of Cement
$= Amt.Cement \times Cement\%\ in\ Concrete\ Industrial\ Grade$

Trends of Cement Market

- Throughput will increase in the next few years but will not exceed peak in 2015
- In the future, construction will move towards maintenance and replacement; cement usage likely to stabilise to 0.4 tonnes/capita/year, similar to the levels in developed countries
- Increasing Prefabricated Prefinished Volumetric Construction with plants situated overseas, cement import into Singapore will decrease

Historical Trend Analysis

Events that cause cement throughput fluctuation:
- General Election 2011; White Paper 2013 with projected population of 6.9mil
- Launch of more than 25000 BTO flat per year from 2011-2013
- Mega Projects such as Marina Bay Sands, Resorts World Sentosa and Changi Terminal 4

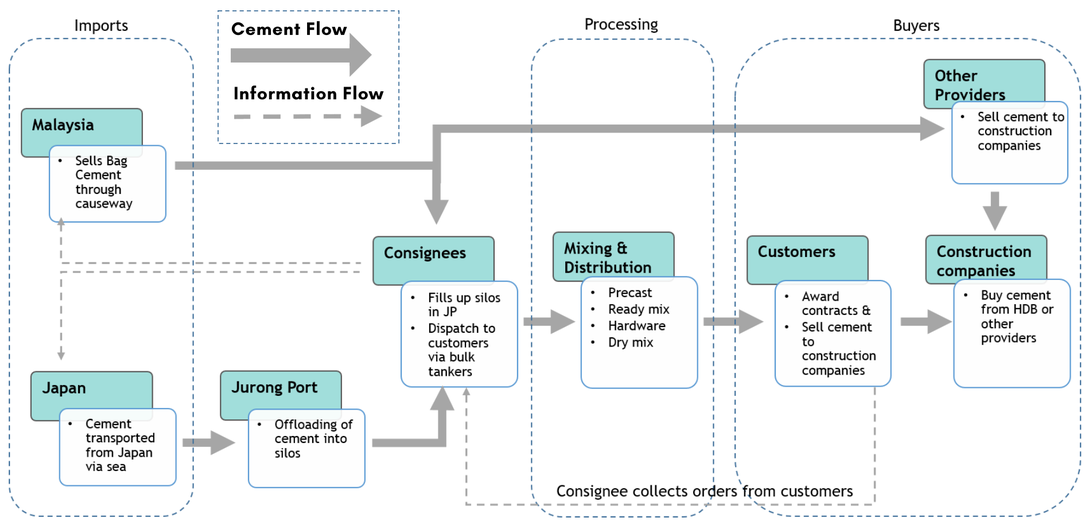
Major Factors associated with Cement Demand & Customers

- Market price of cement dependent on buying price, freight grade, US exchange rate and availability of cement from supplying countries
- Population Target and Growth rates
- Purchasing Managers' Index with 12 months lag
- Progress Payments are an accurate measure of construction activity

Supply Chain of Cement Industry & Associated Costs

Stakeholders of the cement supply chain in Singapore and their relationships were mapped out for Jurong Port's understanding.

Fixed Costs
Port Handling, Trimming, Land Rental, Building Premium, Operating
Variable Costs
Maintenance, Wages, Overtime, Transportation, Cement Purchase



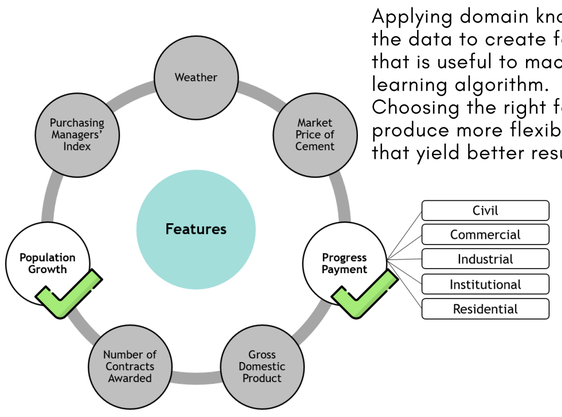
ANALYTICAL APPROACH

DATA COLLECTION

Monthly Cement Throughput from 2004 to 2018 collected from Jurong Port; other relevant data sets from Building & Construction Authority (BCA) and data.gov.sg.

FEATURE ENGINEERING

Applying domain knowledge of the data to create features that is useful to machine learning algorithm.
Choosing the right features produce more flexible model that yield better results.

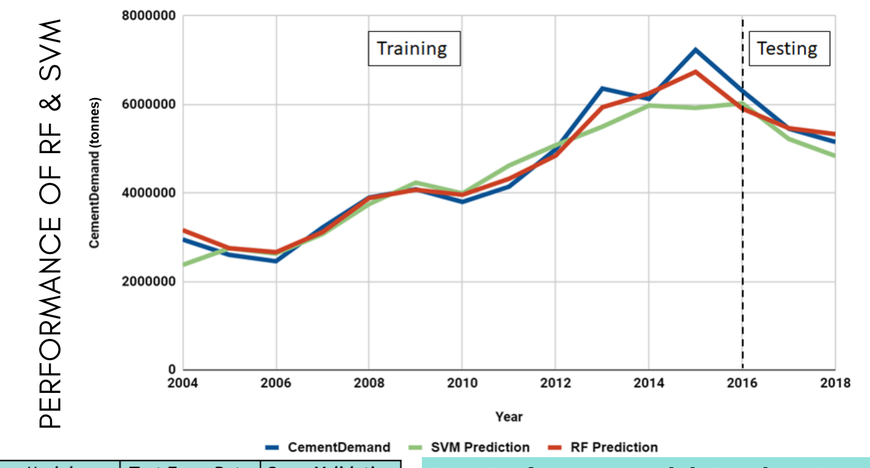


MODEL DEVELOPMENT

Training data: 2004-2015 **Test data**: 2016-2018
Performance Indicator: Mean Absolute Percentage Error

$$MAPE = \frac{Predicted\ Cement\ Throughput - Actual\ Cement\ Throughput}{Actual\ Cement\ Throughput} X\ 100\%$$

Models	MAPE	Limitations
Time Series Models		
ARIMA (Autoregressive Integrated Moving Average)	16.83%	ARIMA fails to capture the trend of cement throughput.
LSTM (Long Short Term Memory)	25.6%	- As a recurrent neural network algorithm, it requires large amount of data for fitting, which is lacking in this project. - Manages to capture trend of cement throughput, but might result in high variance. - Predicting using historical data might not be reasonable in this case.
Supervised Learning Models		
Multilinear Regression	23.56%	- It is too simplistic, resulting in high MAPE. - Nonlinear relationship cannot be captured.
Neural Network	5.04%	It works well in this case.
Random Forest	3.34%	It works well in this case.
Support Vector Regression	4.94%	It works well in this case.



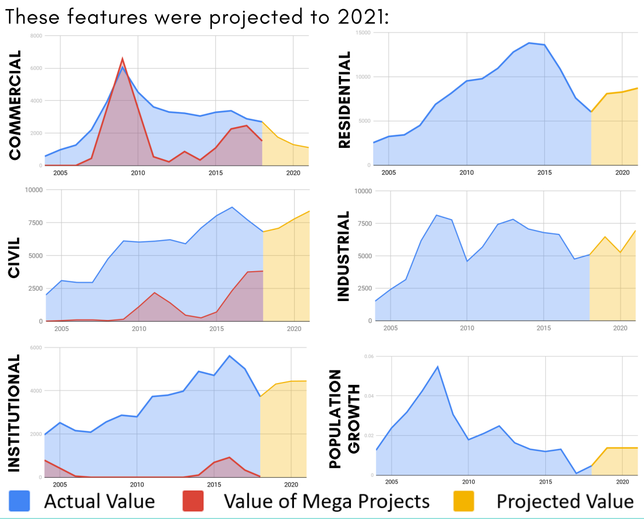
Model	Test Error Rate	Cross-Validation Error Rate
Random Forest	3.34%	11.17%
Support Vector Regression	4.94%	11.08%

Best Performing Model: Random Forest
Chosen as it captures the trend to a large extent; Support Vector Regression fails from 2012-2016.

RESULTS

CEMENT THROUGHPUT PREDICTION

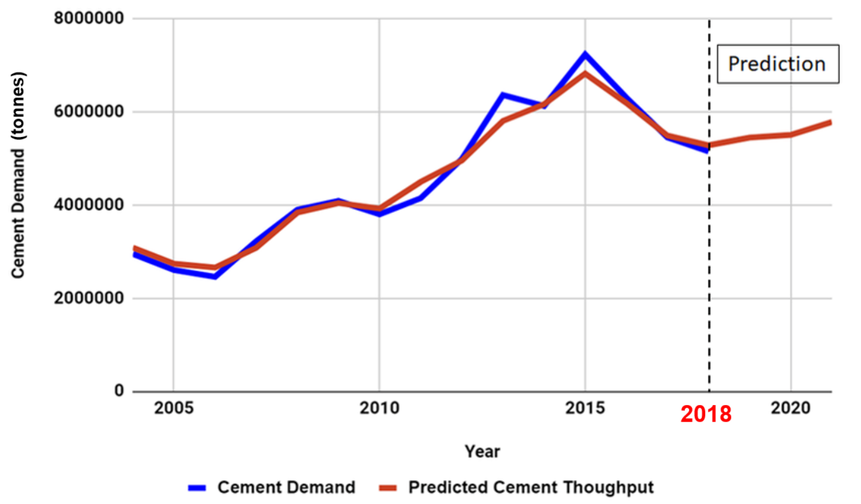
These features were projected to 2021:



Feature Projection takes into account upcoming projects or development plans in addition to historical data and trends.

Effects of mega projects were adjusted for and factors relevant to each sector such as contract values and supply of industrial space were used to project progress payments.

Projected features is used in predicting the cement throughput for 2019-2021



Cement throughput is **predicted to rise steadily over the next three years** but it will not exceed the current operating threshold capacity of the port. **Jurong Port will not need to upgrade port capacity** in the next three years. Prediction result obtained is **corroborated by BCA's report** which predicts construction activity to increase in the next few years. Outlook is influenced by the strong pipeline of public residential, civil and institutional projects.

CONCLUSION

Currently, Jurong Port is employing a multitude of forecasting methodologies to predict cement throughput.

Industry approach provided insights into the cement industry for Jurong Port and assisted the predictive modelling process in **Analytical approach**.

As cement demand in Singapore is largely determined by upcoming projects and government plans, the design incorporates the functionality to factor in future construction projects.

Therefore, the forecast tool was created to provide an additional validation for existing cement throughput forecast. The tool generates realistic and reasonable forecast as factors affecting construction activity in Singapore are considered.