Optimisation of Multi-Commodity, Multi Vehicle Supply Chains in Construction

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1. INTRODUCTION

In the UK, an estimated 10 to 20% of a construction project's costs is allocated to logistics and transportation of material (Building Research Establishment, 2003). An inadequately managed and designed supply chain can give rise to project delays, disorganised vehicle routing and ultimately, higher costs. Therefore, there is a need to optimise the transportation process with a more rigorous, mathematical approach. The aim of this project is to realise the benefits of an optimised supply chain network with the use of Mathematical Programming techniques.

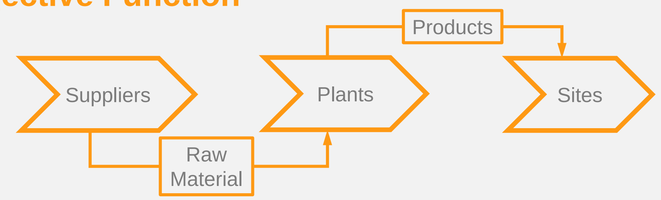
2. METHODOLOGY

The scope of this project was to develop two Mixed Integer Linear Programming (MILP) models that could be used to find the optimal production-distribution schemes for the specified supply chain networks. The principal networks that were developed consisted of a 3-stage and 4-stage model. The MILP formulations were designed to find optimal production levels for multiple products to satisfy demand at the construction sites, assign multiple vehicles from a fleet to meet logistical demands and find the optimal level of storage at specific facilities. The models minimised the Total System Costs, with contributions from transportation, production and storage processes. In order to develop the appropriate tools for analysis, the following methodology was followed:

Literature Review → 3-Stage Supply Chain Model → 4-Stage Supply Chain Model → Stochastic Variations → Data Generation & Case Study → Output Analysis

Total System Cost (TSC) Minimisation

Objective Function



Decision Variables

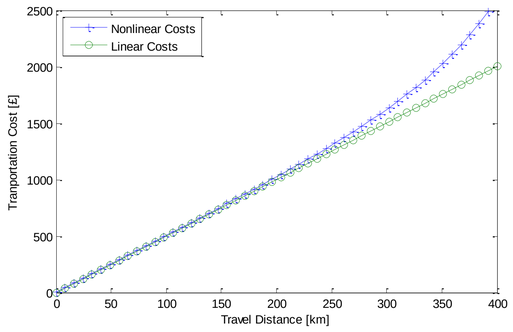
- Vehicle assignment (Boolean)
- Production levels
- Storage on site and in warehouse

$$Minimise^*: \; TSC = \underbrace{\sum_{i}^{I}\sum_{j}^{J}\sum_{r}^{R}\sum_{v_1}^{N} A_{ijrv_1}C_{ijv_1} + \sum_{j}^{J}\sum_{k}^{K}\sum_{p}^{P}\sum_{v_2}^{N} A_{jkpv_2}C_{jkv_2}}_{\text{Transportation costs from vehicle assignment}} + \underbrace{\sum_{p}^{P}\sum_{j}^{J} x_{pj}C_{pj}}_{\text{Production Costs}} + \underbrace{\sum_{p}^{P}\sum_{k}^{K} S_{pk}C_{pk}}_{\text{Storage Costs}}$$

*Subject to constraints

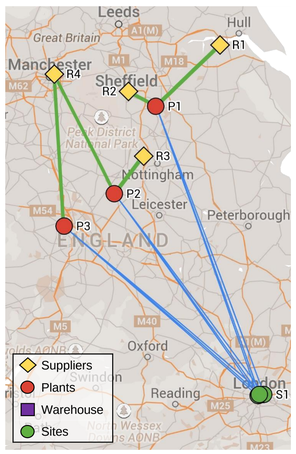
3. STOCHASTICITY

Stochastic conditions were simulated using scenario type analysis. Demand uncertainty was modelled by observing the effects of varying rates of return of a delivered product back to its origin. Travel time unreliability was modelled using an exponential cost function, that reflected the worst-case costs associated with congestion, breakdowns, and other factors that may incur extra costs to the operator. The cost function was defined to be relative to the distance travelled.



4. CASE STUDY

Numerical data was generated to capture a supply chain of a main contractor in the UK. Travel distances were found between the raw material suppliers, manufacturing plants and construction sites and three products and four raw materials were modelled. A fleet of vehicles were generated, with vehicle operating costs and capacities.

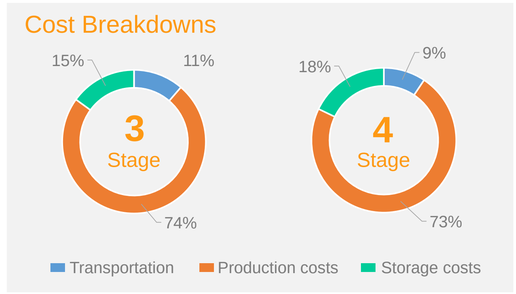


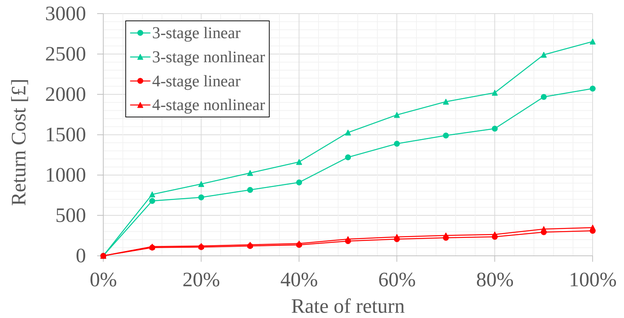
Vehicle Data

Small	Large
7.5 t	17 t
£0.35 / km	£0.39 / km
30 vehicles in fleet	60 vehicles in fleet

4. RESULTS

After solving the various models, it was found that transportation costs were significantly reduced when a consolidation centre was included into the supply chain. The deterministic solutions showed that there was a 19% decrease in transportation costs, whilst storage costs increased by 16%. Stochastic solutions suggested that the use of consolidation centres drastically lowered return costs, as the distance between the construction sites and the point of origin was reduced.





Further research could be allocated to the inclusion of lead times within the formulation; introducing consolidation centres to the supply chain has a significant effect on lead times, as handling times for goods within the warehouse add to the overall lead time.

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REFERENCES

Building Research Establishment (BRE). (2003) *Construction Site Transport: The Next Big Thing.* BRE Ltd: Watford.