Logistics Optimization: Loading Trends, Operational Hotspots and Performance Analysis

A Midterm Report for the Business Data Management Capstone Project

Submitted by

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Executive Summary

The collected data, spanning from January to November 2023, is cleaned to focus on the headhaul trips from OCL, the company with which the firm has the cement partnership. Some key performance indicators are used to describe the firm's performance. The operational dynamics between the owner-operated and third party trucks is also discussed. Exploratory and time series analyses are conducted using Excel to visualise the monthly and daily trend in loading.

The analysis reveals that the high (January-March and end of each month) and low (September-November and the beginning of each month) business period. These insights will help the firm in arranging third-party trucks during periods of peak demand, thereby solving its first business problem.

Metadata

Before data cleaning: With the owner's consent, I have collected a comprehensive dataset from the manager of the cement division of the firm. This dataset, spanning from January to November 2023, is organised into monthly spreadsheets and includes daily ledger entries such as trip details, fines, repair costs, tolls, and more. Each entry includes the date, purpose, description, associated personnel in the "remarks", and the cash balance before and after the entry.

For trips, additional details are provided, including truck number, wheel count, driver or third-party name in the "remarks", unloading destination in the "description", loading quantity, advance payment made to truck before the trip for operational expenses, the refuelling station, company-provided freight rate per ton, third-party freight rate per ton*, number of cement bag shortage in the trip and outstanding payments to third parties*.

*These are provided only if the truck is third-party owned.

Data cleaning: The spreadsheets, while comprehensive, were not in an analysis-friendly format and contained extraneous information. To address this, I initiated a data cleaning process. I first filtered the "purpose" column to retain only entries about trips originating from the OCL factory. Subsequently, I consolidated all entries into a single Excel file. Irrelevant fields were removed, leaving only key data variables such as date, truck number, wheel count of the truck, description, remarks, loading quantity, total advance

payment, the refuelling station, company-provided freight rate per ton, number of cement bags shortage, third-party freight rate per ton, and outstanding payment. The data was further cleaned and processed in the following steps:

1. The unloading destination name was extracted from the “description” field using the *text to columns* feature.
2. A new column was added to identify the third party name from the “remarks” field. The formula used:

   If (fare given to third party > 0)
   then entry = entry of the “remarks” field
   else entry = "own"

is effective in distinguishing between the owner’s trucks and third-party trucks. This is because the value for the field “fare given to a third party” is zero for the owner’s truck, indicating no third-party involvement. Hence, this allows for an accurate determination of truck ownership within the dataset.

3. In order to identify the driver associated with each trip done by the owner’s truck, an additional column was introduced. The following formula was used to:

   If (third party name = "own")
   then entry = entry of the “remarks” field
   else entry = "third party"

It ensures that if the trip is conducted by the owner’s truck (indicated by the “third party name” column entry as “own”), the driver’s name is directly extracted from the “remarks” field. Conversely, if the truck belongs to a third party, the entry is simply marked as “third party”.

4. The “Net Revenue for a Trip” column was calculated using the following formula:

Net Revenue = loading quantity * company-provided freight rate per ton - number of cement bag short * 308

This formula takes into account the payment provided by the company, which is the product of the fare per ton and the loading quantity (in tonnes). This can be considered as the “selling” price of the firm’s service. However, if there is a discrepancy in the number of cement bags loaded versus unloaded, the company deducts the cost at a rate of Rs. 308

per cement bag before making the payment to the firm. This adjustment is crucial and needs to be adequately reflected in the net revenue calculation.

5. Based on the owner's insights, a unique identifier was established for headhaul-only trips. If the "fuel station" column entry is "PFS" (Picnic fuel station), it signifies that it was a headhaul-only trip, as a different fuel station is used for round haul trips. Only fuel cost from this station is given as advance in this dataset. The cost from any other fuel station is not given, as it is recorded separately along with the backhaul trip details. This information was utilised to populate a new "headhaul only trip" column using the following logic:

   If (fuel station = "PFS")

   then entry in the "headhaul only trip" column = "Yes"

   else entry = "No"

This method ensures accurate categorisation of trips, enhancing the dataset's utility for subsequent analysis.

6. The fuel cost for round haul trips is recorded as zero in the dataset, due to the reason mentioned above. This lack of accurate fuel cost data could potentially lead to an overestimation of profit per trip. Therefore, profit calculations were exclusively performed for headhaul-only trips using the following formula:

   If(headhaul only trip = "Yes")

   then profit = net revenue for the trip - Advance given for the trip - outstanding payment to the third party (or 0 if it's the owner's)

   else profit = 0 (for unknown)

This formula accounts for the total advance, which includes fuel cost, driver salary, and other operating costs for the owner's truck, or the advance payment given for the trip to the third-party truck. It also considers the additional cost for third-party trucks, as they are not fully paid in advance for their service. This cost is subtracted from the revenue generated in the trip to calculate the actual profit.

7. In the final stage, entries with inconsistent or incomplete information, such as missing dates or truck numbers were removed from the dataset. Additionally, the "remarks",

"description" and "fuel station" fields were deleted as they were no longer necessary for further analysis.

After data cleaning: The cleaned dataset now contains comprehensive details about all headhaul trips from OCL, from 1st January to 20th November 2023. It includes fields such as date, truck number, number of wheels in the truck, destination, loading quantity in tonnes, trip type (headhaul only or roundhaul), total advance, third-party name, driver name, freight rate, cement shortage, net revenue, fare given to third party, outstanding amount, and profit.

However, it is important to note the limitations. The dataset lacks information about the backhaul trip, so profit calculations are going to be approximations. Additionally, the absence of delivery dates prevents the calculation of key performance indicators like delivery time. This dataset will be used for further project analysis.

Descriptive Statistics

The dataset comprises **1,336 data points**, each representing a trip made during the specified period. Of these, **677 trips (or 51%) were headhaul-only trips**.

The freight rates varied across destinations, with Kalna offering the highest rate of Rs. 862 per ton and Jamkuri, Patraseyar offering the lowest rate of Rs. 460 per ton. However, Asansol was the most frequented destination with 419 trips and a total loading quantity of 6,328 tonnes.

In terms of vehicle usage, six-wheelers accounted for the majority of trips (53%), while ten-wheelers handled the most loading quantity (44%).

From January 1st to November 20th, a span of 324 days, entries were recorded on 287 days only. This indicates that there were 37 days (approximately 11% of the period) with no loading activity. A frequency distribution of the number of trips is given by figure 1.

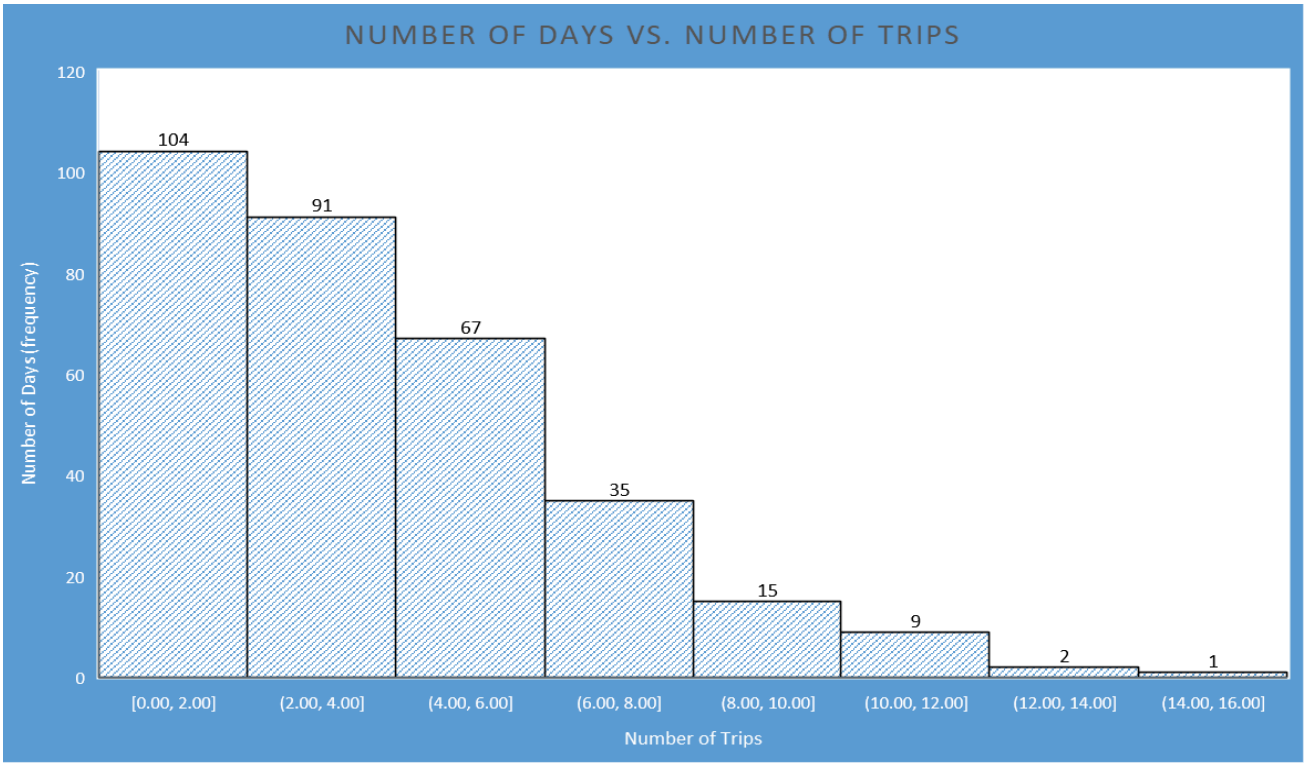

Figure 1: Histogram representing the frequency distribution of number of trips

The firm's performance can be further evaluated using three key performance indicators (KPIs) as follows:

1. **Loading Quantity**: It reflects the firm's delivery capacity. The modal loading quantity is 13, aligning with the 6-wheelers' capacity, the most frequently used truck.
2. **Revenue**: It provides insight into the firm's sales performance. The average revenue is Rs 11,222.65 and the standard deviation is 4,197.49, indicating variability due to freight rate differences and loading capacities.
3. **Profit**: It measures the firm's profitability. The total profit from headhaul-only trips is Rs 8,23,265. Round haul trips, accounting for 49% of all trips, are expected to yield higher profits due to efficient utilisation of resources like fuel, time and human resources.

Table 1 provides a detailed summary of the descriptive statistics of these KPIs, calculated using respective Excel formulas.

* The standard deviation calculated is for the entire population, as the data encompasses all headhaul trips.

Variable name	Total	Mean	Median	Mode	Maximum	Minimum	Standard deviation *	Kurtosis
Loading quantity (in tonnes)	21,290	15.94	13	13	45	10	4	1.93
Revenue (in rs)	1,49,93,464	11,222.65	9,360	7,956	25,860	- 1,544	4,197.49	0.59
Profit for headhaul only trips (in rs)	8,23,265.00	1,216.05	324	240	10,850	- 4,775	1,796.18	4.19

Table 1: Descriptive statistics of the KPIs of the firm

The firm primarily uses the owner's trucks, which performed 315 out of 677 headhaul-only trips and all the backhaul trips. Third-party trucks are utilised exclusively for headhaul trips from OCL due to the existing cement partnership. The absence of additional partnerships limits the engagement of third-party trucks. This strategy results in a significant portion of the business being handled by owner's trucks, as seen in Table 2.

Ownership Type	Total profit for headhaul only trips (in Rs)	Total Loading quantity (in tonnes)	Total Number of trips	Total Revenue (in Rs)
Third party	1,19,065.00	7,137	362	56,31,095
Own	7,04,200.00	14,153	974	93,62,369

Table 2: Comparison between third parties' and the owner's trucks

It is noteworthy that though the average profit per trip is Rs. 1,216.05 (from table 1), there's a significant disparity between the profits from the owner's trucks and those from third parties.

Average profit per headhaul-only trip for owner's truck = $\frac{Rs.\,7{,}04{,}200.00}{315}$ = Rs. 2,235.56

Average profit per headhaul-only trip for third party truck = $\frac{Rs.\,1{,}36{,}313.00}{362}$ = Rs. 376.56

This observed difference in average profit can be attributed to the firm's freight rate policy. The firm has to adhere to the market standards when setting freight rates for third

parties, which are typically Rs 30-40 less than the company's fare. This results in a significantly lower income from third-party trucks compared to owner-operated trucks.

Analysis Process/Method

The goal is to analyse the monthly and daily trends in the trip count and loading quantity using exploratory and time series analysis. This will help identify the firm's busy periods, allowing for development of a strategy to ensure timely arrangement of third-party trucks during those periods, thereby addressing the first problem of the firm.

To achieve this, a pivot table was used to aggregate the date as row and the daily loading quantity and trip count as values. To effectively visualise this trip pattern given the large number of data points, a heatmap was created using the daily trip count data (Figure 2).

Furthermore, Excel's TEXT formula was used to extract the weekday from the date. A pivot table was then used to compile the total loading quantity and trip count and the average trip count for each weekday (Table 3). As per Table 3, Sunday and Wednesday had the highest number of trips and loading quantities, which are almost 38% and 35% higher respectively than Monday, the least active day with 3.28 trip count on average.

Day	Total Loading quantity(in tonnes)	Total Number of trips	Average trip count per day
Sunday	3347.5	213	4.53
Monday	2486	154	3.28
Tuesday	3041	191	4.15
Wednesday	3356.5	214	4.65
Thursday	2756	173	3.76
Friday	3228	197	4.28
Saturday	3075	194	4.22

Table 3: The total loading quantity and number of trips for each weekday

Months	Total Loading quantity (in tonnes)	Total trips	Average loading per day(in tonnes)	Average trips per day
January	2,814.0	177	91	6
February	3,136.0	191	112	7
March	3,475.0	209	112	7
April	2,037.0	119	68	4
May	2,350.0	143	76	5
June	1,603.0	106	53	4
July	1,862.0	124	60	4
August	1,672.5	106	54	4
September	632.5	43	21	1
October	983.0	67	32	2
November	725.0	51	36	3

Table 4: The total and average loading quantity and number of trips for each month

The data in table 4, obtained via pivot table, was used to plot a line graph to visualise the monthly trend, which is effective for this purpose as it clearly depicts changes over month, allowing for easy pattern identification. Given the high positive correlation coefficient of 0.997 between total number of trips and total loading, Excel's *trendline* feature was used to plot the regression line (Figure 4) only for the monthly trip count. The best fit line, $y = -15.173x + 212.49$ with $R^2 = 0.8269$ demonstrates a downward trend, as suggested by its negative slope.

The observed trend in Table 4 and Figure 4 confirms the hypothesis that demand typically dips during the monsoon season (June-August) averaging around 4 trips per day, and peaks

towards the end of the financial year (January-March), with an average daily trip of 6-7 per day. However, an anomaly is observed during the months of September-November. Despite expectations of high demand due to the festive season, the data reflects a significant reduction in the average trip count to 1-3 trips daily.

Further analysis will be conducted and detailed in the final report.

Results and Findings

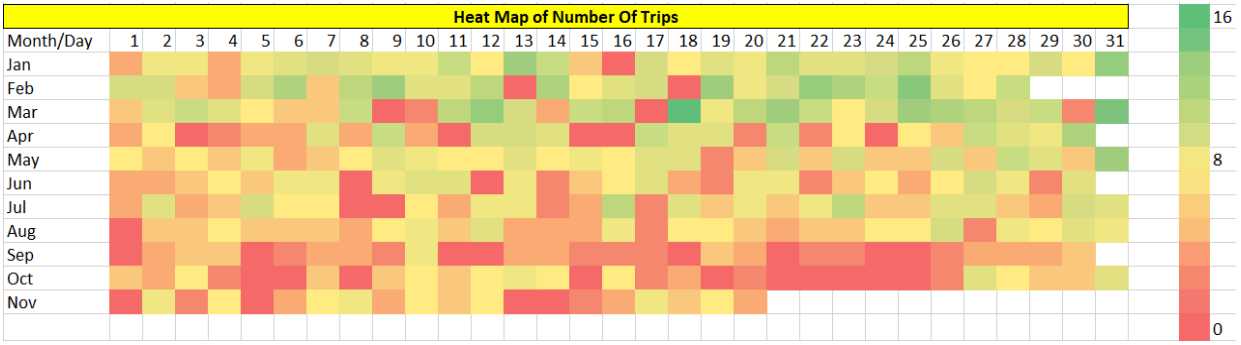

Figure 2: Heat map representing daily trips count from 1st january - 20th november, 2023

As depicted in Figure 2, there is a consistent trend of **high loading towards the end of each month (27th-31st), while the beginning of the month (1st-4th) tends to be slower for business**. This pattern can be attributed to the operational dynamics of OCL. Its orders typically increase towards the end of the month due to its target fulfilment requirements.

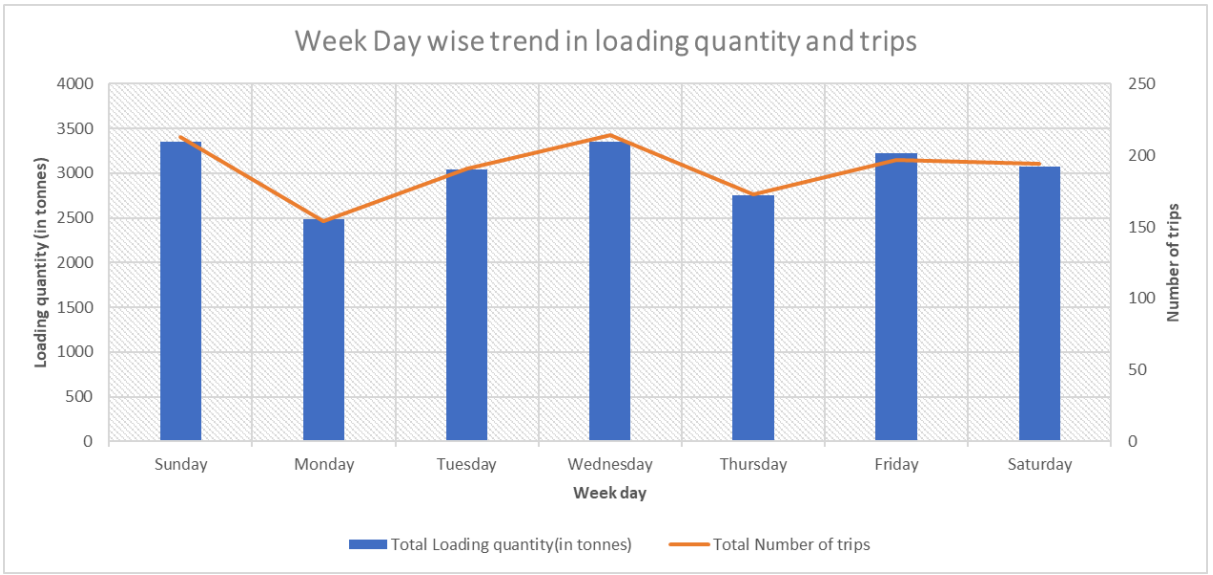

Figure 3: Barchart & line graph showing week day wise trend in loading quantity & trips

The loading pattern observed in Figure 3, with **the highest loading on Wednesdays and Sundays and the lowest on Thursdays and Mondays**, can be attributed to the delivery time and scheduling of backhaul trips. The backhaul trips are scheduled for alternate days, as a truck takes 1-2 days on average to return back to the factory. This leads to fluctuations in the loading by the owner's truck at OCL.

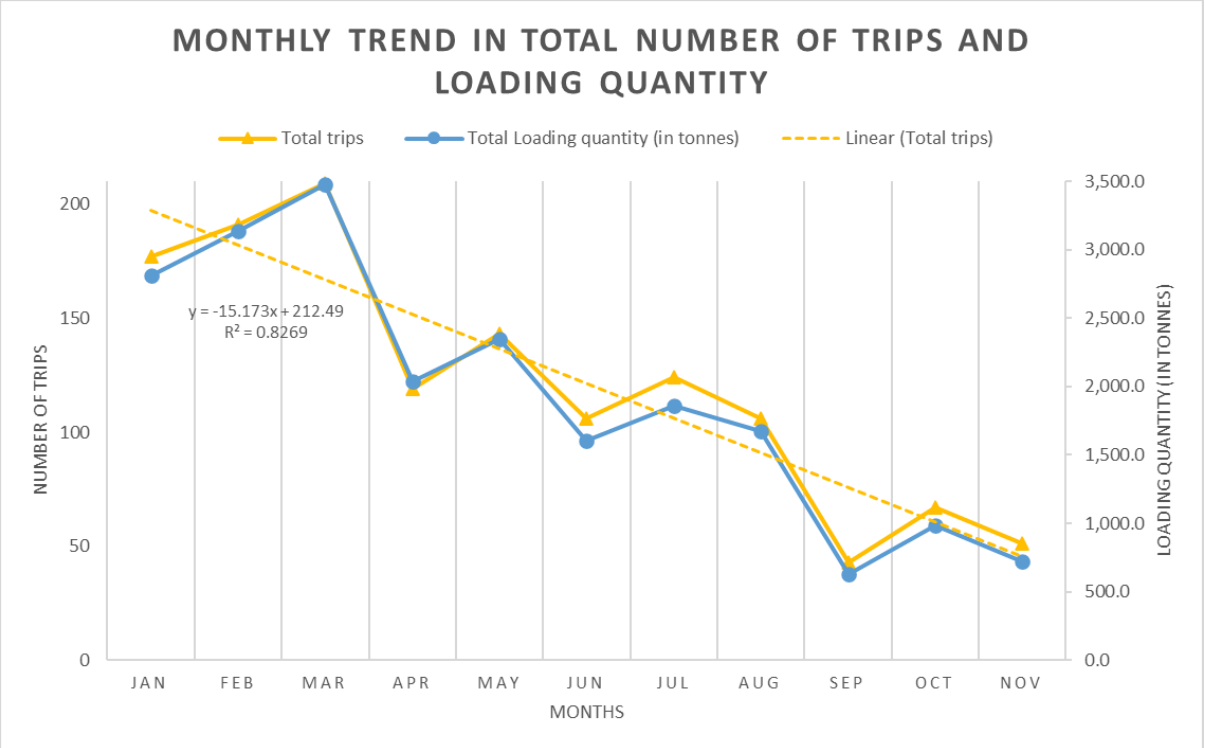

Figure 4: Line graph for the monthly trend in loading quantity and number of trips

Figure 4 reveals a correlation between the loading quantity and trip, which is expected as a higher number of trips would naturally lead to an increased loading capacity. **The observed downward trend in loading suggests a decreasing demand over the months.**

The busiest period for the firm is from January to March. This surge can be attributed to OCL's need to meet its annual targets, leading to an increase in shipment orders.The demand dips in the monsoon season due to decrease in construction work, hence reduced demand for cement. Interestingly, business activity significantly declines during the festive season in September-November, even more so than during the monsoon months. During this period, many drivers are unavailable due to celebrations at home, impacting the availability of owner-operated trucks, which constitute a significant portion of the firm's operations.