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District Level Freight Production of Agricultural commodities in India

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Abstract

Freight transportation has a key role in the economic competitiveness of any nation. It connects all the economic activity centres, agricultural production areas, natural resources and international gateways. India is one of the fastest growing nations in the world with a GDP growth of 7.11% during 2016-17 (Ministry of Road Transport and Highways, Government of India). In India, agricultural sector plays a vital role contributing significantly to the country’s economy. India stands as one of the leading producer of several agricultural products in the global market. Agricultural commodities occupy the major share in the commodity shipments by road, which shares 65% of the total freight movement in India. This indicates the importance of the sector and need for modelling of the freight volumes of this sector. In this paper, the freight production in the agricultural sector of India has been modelled using multiple linear regression analysis. Models employing logarithmic transformations and interaction effects are developed and compared. The factors influencing the production of agricultural freight were identified and the relationships between freight productions and influencing factors were analysed.

Keywords: Freight generation; Agricultural commodities; Regression analysis; Logarithmic transformation; Interaction effects.

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1. Introduction

India is one of the fastest growing economies in the world. The country’s transport sector is growing at a greater pace than its Gross Domestic Product (GDP). Freight transported by road has been increased at a compounded annual growth rate (CAGR) of 9.06% during the period 1950-1951 to 2007-2008, whereas growth of GDP at market price (CAGR) was observed as 7.35% during the same period (Transportation Corporation of India Limited (TCIL) & Indian Institute of Management Calcutta (IIM-C), 2009). Freight transportation in India has increased momentously over past

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two decades. Freight transported through road and rail was increased from 257 billion ton kilometers (BTKM) in 1980-81 to 2053 BTKM in 2011-12 (Ministry of Road Transport & Highways, GOI). This indicates the growth of freight demand and the importance of modelling of freight demand in India. The country is facing several challenges in the freight transportation sector. In spite of huge growth in freight demand and need for improvement, unfortunately there is no proper systematic framework to model the freight demand in India. Though there are investments over freight infrastructure, congestion and shortage of capacity is exhibiting in the sector and need for capacity to be enhanced is seen every decade (Planning Commission, GOI, 2013). It is important to predict the future freight flows and their patterns in order to increase the efficiency of movement of freight especially in developing country like India.

Freight transportation demand can be divided into four different classes; urban, regional, national and international based on the distance of haulage. In Europe, the countries have developed national freight demand models whereas in United States and China, there are state wide freight demand models. In India, regional freight demand models are needed to assist the government in policy and decision making for future transport infrastructure. India is a vast country with 29 states (administrative divisions) and six union territories comprising of 640 districts (administrative divisions within the states). The states have been regrouped into six zones namely, Northern, Central, Western, Eastern, North-eastern and Southern. The transport system in India consists of different modes such as rail, road, coastal shipping, inland waterways, pipelines and air transport. Rail and road transport are dominating carrying around 87% of the total freight traffic in the country during 2007-08 (National Transport Development Committee, 2015).

Forecasting of freight volume is the basis for the prediction of freight generation and flow. The freight flows are measured in two ways: (i) commodity and (ii) truck/vehicles. The models that deal with the commodity movements, where the focus is on the amount of freight produced/attracted and distributed in terms of weight are termed as commodity based models and those concerned with vehicle trips are trip based models (Holguín-Veras & Thorson, 2000). The modelling methods of freight generation that have been in practice are Trend and time series models, Zonal trip rate models, regression models and Input-Output related models (de Jong, Gunn, & Walker, 2004). In trend models, the past trends of freight productions/attractions are extrapolated into future by applying growth factors. Time series models uses information on vehicle flows and require various data points for the same facility. In Zonal trip rate models, trip rates for production and attraction are derived from classifying the cross-sectional data of transport volumes from various origin zones to various destination zones in the study area into a number of homogeneous zone types. These trip generation rates are developed by conducting trip dairy surveys or national default data (Cambridge Systematics, 2007). Input-Output models attempt to quantify the relationship Regression models are the statistical models which try to relate different variables in the form of regression equations (Tavassy & De Jong, 2014). In freight demand forecasting, regression equations are developed for a zone based on the economic conditions and different equations are developed for different commodities or group of commodities similar to trip purpose wise regression equations in passenger travel. Regression models are the commonly used models when the modelling is at aggregate level (Pendyala, Shankar, & McCullough, 2000). Ordinary least square regression and cross classification models were developed to identify the relationship between freight deliveries and establishment attributes (Bastida & Holguín-Veras, 2009). Simple linear regression, multiple linear regression and non-linear regression methods were used for predicting transportation demand at regional level and were found to perform efficiently (Yang, 2015). Robust regression was used to model the freight generation which minimizes the effect of outliers present in the data (Brogan, Brich, & Demetsky, 2002). Linear regression models with spatial regression variables were investigated modelling freight generation at national level (Novak et al., 2011). In this paper, multiple linear regression models (i) using logarithmic transformations and (ii) introducing interaction effects were developed to model the freight production in agricultural sector based on freight volume data and different variables influencing its demand.

1.1. Role of Agriculture in Indian economy

Agricultural sector plays an important role in Indian Economy. Over 58% of the rural population in India depends on agriculture as it is their primary means of livelihood. The share of agricultural and allied sector is estimated to be 20.4 percent of the Gross Value Added (GVA) during 2016-17 at current prices (Ministry of Finance, GOI, 2017). India is emerging as the largest producer and exporter of several agricultural products (Spices, pulses, milk, tea, cashew and jute) in the world market and stands second in the production of wheat, rice, fruits and vegetables, sugarcane, cotton and oilseeds (IBEF, 2018). Agricultural exports occupy 10 percent of its total exports and ranks fourth among the principal commodities. India ranks first with 179.8 million hectares making 9.6 percent of global net cropland area (Ministry of Finance, GOI, 2018). Road freight constitutes around 65% of the total freight transported in India and agricultural commodities occupy a significant share in that. Figure 1 shows the percentage shares of various commodity shipments by road during the year 2007-08 (RITES Ltd., 2014). It is evident that agricultural commodities occupy second most share among the road freight where miscellaneous freight which include gas cylinders, empty tins, bottles, drums, provisions and household goods, containers, parcels etc. have the major share. This indicates the importance of movement and need for modelling of agricultural commodities in the country.

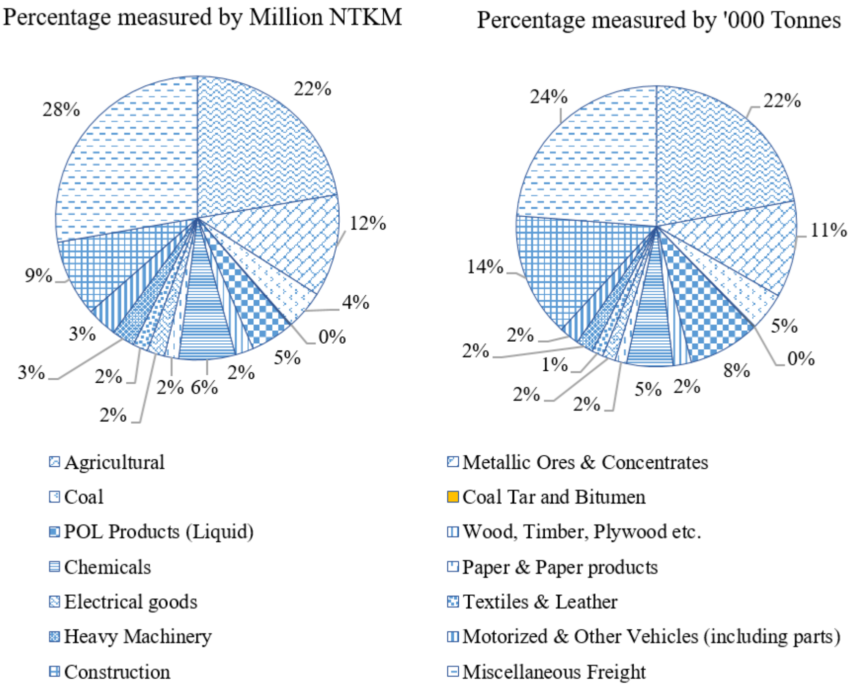
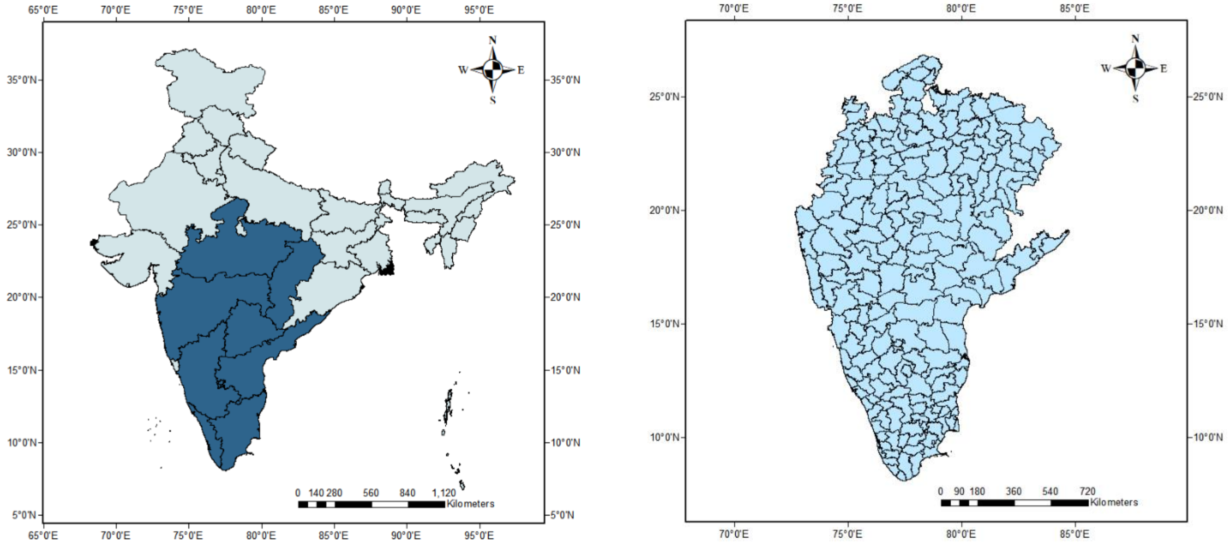


Fig. 1. Share of various commodity shipments transported by road during 2007-08

2. Study Area

The study area comprises of eight states namely Andhra Pradesh, Chhattisgarh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Tamil Nadu and Telangana, covering South India and parts of Central and Western India. Each state comprises of districts (administrative divisions within a state) similar to counties in United States and sub prefectures in China and Japan. These districts are considered as Freight Analysis Zones (FAZs) for modelling. For the present study, a total of 199 districts have been considered. The newly formed districts of Telangana state were not considered due to data unavailability. The old districts in ten number were considered. The study area covers around 42% of the country's area and around 36% of country's population. Figure 2(a) shows the study area with the eight states highlighted in dark blue color and 2(b) shows the freight analysis zones, i.e. the study districts.



(a) (b)

Fig. 2. Maps showing (a) Study area (b) Freight Analysis Zones

3. The Data

In United States, Commodity Flow Survey (CFS), a component of Census Bureau's economic census which is conducted for every five years is the primary data source for state level and national level data on commodity shipments. Various data on origins and destinations, weight and value of commodities, mode of transport, distance and ton-miles transported are available through this (Bureau of Transportation Statistics, U.S. DOT). European countries have commodity flow survey databases separately for each country where the various data on commodity movements within the nations, across EU and international shipments are collected. In India, there is no specific database available on commodity movements. The data for the present model have been collected from state and district government website databases. The data contain information on socioeconomic details, production of commodities and other district statistics. Population and Employment data have been obtained from Census India database and district census statistics. Indian Census is the largest source of statistical information about socio-economic data which is decennial. The latest data available is for the year 2011. Apart from this, local government bodies of states maintain their own databases for district level statistics. For employment in agricultural sector, the agricultural laborers and cultivators have been considered. Sector wise district domestic product data have been obtained from Directorate of Statistics and Economics database of respective states. The data related to agricultural sector such as gross cropped area, gross irrigated area, annual rainfall and crop production data have been obtained from annual crop and season reports and annual agricultural statistics that are available from local state government databases.

3.1. Construction of variables and data pre-processing

In past studies, employment and population were most commonly used independent variables for estimating freight generations (Cambridge Systematics, 1996, 2007; Brogan et al., 2002; Mirjam & Wilhelm, 2002; Bastida & Holguín-Veras, 2009; Holguín-Veras et al., 2013). The variables used for modelling should be quantifiable, easily obtainable and should be able to forecast reliably. Therefore, variables those are obtainable from public and government sources are considered in this study. The predictor variables considered for the present model are Population (POP), Employment in agricultural sector (EMP_{AG}), District Domestic Product of the agricultural and allied sectors (DDP_{AG}), Gross Cropped Area (GCA), Gross Irrigated Area (GIA), and Annual Rainfall (RF). The predicted variable is the volume of freight produced i.e. Crop Production (CP). The variables considered, coding used and their sources of data are given in Table 1.

Table 1. Coding and data sources of variables.

Variable	Code	Original data source
Population (‘00000 persons)	POP	Census of India database
District Domestic Product of agricultural sector (₹ ‘00’ crore)	DDP_{AG}	Directorate of Economics and Statistics database of respective states
Employment in agricultural sector (‘00000 persons)	EMP_{AG}	Census of India database
Gross Cropped Area (‘000’ hectares)	GCA	Directorate of Economics and Statistics database of respective states
Gross Irrigated Area (‘000’ hectares)	GIA	Directorate of Economics and Statistics database of respective states
Annual Rainfall (Centimeters)	RF	Directorate of Economics and Statistics database of respective states
Crop Production (‘000’ tonnes)	CP	Directorate of Economics and Statistics database of respective states

As there is no readily available commodity flow data base, the construction of data for the model is a challenging task in the process of model development. The basic assumption of the model is the relation between the response variable and the predictor variables will not change with time. This means, the data considered for each FAZ can correspond to different base years. Population data for all FAZs are available for the year 2011. For those FAZs, whose population data is needed for different base year and is not available, they were calculated using the decadal growth rates available from census database. The average annual growth rates were obtained through decadal growth rates and were applied to determine the population for the required base year. Employment data for all FAZs are available for the year 2011. To obtain the data of required base year, the percentage of employment out of total population of the FAZ for the year 2011 has been applied to the required base year data with an assumption that the percentage of people employed in agricultural sector remains constant during that period. DDP_{AG} data measured at constant 2011-12 prices have been considered. For those FAZs with DDP_{AG} of different base year (Base year here represents the year taken as base for GDP calculation; e.g. constant 2004-05 prices), they have been converted to the constant 2011-12 prices.

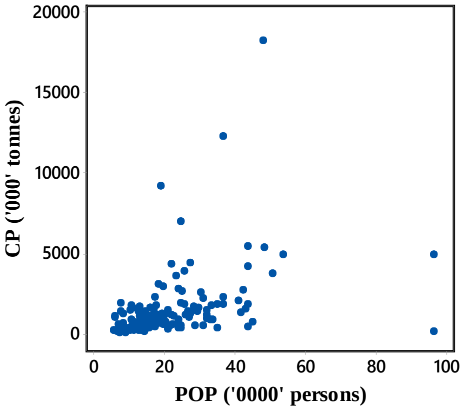
4. Descriptive analysis

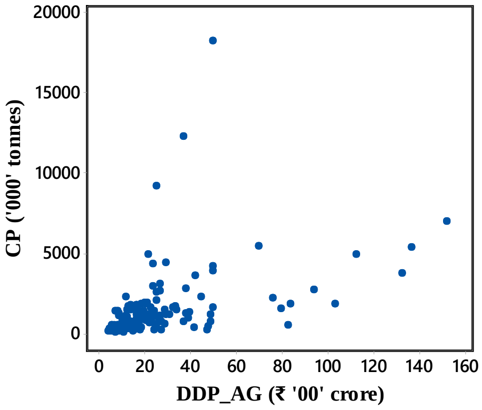
The average population of FAZs is 2.31 million. The FAZ with highest population is Mumbai, district in the state of Maharashtra with 16.05 million and the FAZ with least population is Dantewada in the state of Chhattisgarh with 0.54 million. The average employment in agricultural sector is found to be 0.53 million. Nashik district in the state of Maharashtra stood top with the highest employment in agricultural sector with 1.65 million and Chennai, the district of Tamil Nadu has the least of 0.029 million. The district domestic product of agricultural sector is highest for Nashik with ₹151.73 thousand crore and lowest is Gadchiroli with ₹1.97 thousand crore, both the districts belongs to the state Maharashtra. The average DDP_{AG} of all FAZs was found to be ₹28.48 thousand crore. Ahmednagar of Maharashtra has the highest Gross cropped area of 1282 thousand hectares and the districts Mumbai, Chennai, Hyderabad of the states Maharashtra, Tamil Nadu and Telangana respectively stands at the bottom with no cropped area. These districts are metropolitan areas and barely have any cropped area. The same is the case with gross irrigated area where the districts Chennai and Hyderabad are lowest and West Godavari district of Andhra Pradesh with Godavari river basin has highest gross irrigated area of 624 thousand hectares. The average gross irrigated area of all FAZs has been found to be 115.16 thousand hectares. The average annual rainfall was found to be 115.16 centimeters. Coimbatore of Tamil Nadu state experienced least annual total rainfall of 33.53 centimeters and Udupi of Karnataka state experienced highest of 1022 centimeters.

The data set of predictor variables and the response variable were analyzed to understand the relation between them. Figure 3 shows the graphs plotted against crop production and the predictor variables. The plots show that freight volume increases with increase in the predictor variables, but there exists non-linear relationships between them. The Pearson correlation between the variables has been given in Table 2, the correlation matrix. From the matrix, it is evident that no two predictor variables are highly correlated among themselves and all of them can be considered in the model. Employment and District domestic product are highly correlated to the production among all the variables. It can be seen that rainfall has a very less and a negative correlation with the crop production. From the data, it has been observed that rainfall is barely related to crop production. For example, in Mumbai, the total annual rainfall for the year 2013-14 was 456 cm and the crop production was zero tonnes whereas Ahmednagar with 36 cm of total annual rainfall produced 10902 thousand tonnes in the year 2013-14. But, there is a possibility of interaction of rainfall with other variables and that is discussed in the next section.

Table 2. Correlation matrix.

	POP	DDP$_{AG}$	GCA	EMP$_{AG}$	GIA	RF	CP
POP	1						
DDP$_{AG}$	0.4571	1					
GCA	0.0905	0.3903	1				
EMP$_{AG}$	0.3420	0.6804	0.6478	1			
GIA	0.1309	0.5314	0.5784	0.5224	1		
RF	0.0569	-0.214	-0.3177	-0.3306	-0.3193	1	
CP	0.3569	0.4284	0.4138	0.5532	0.2468	-0.0809	1





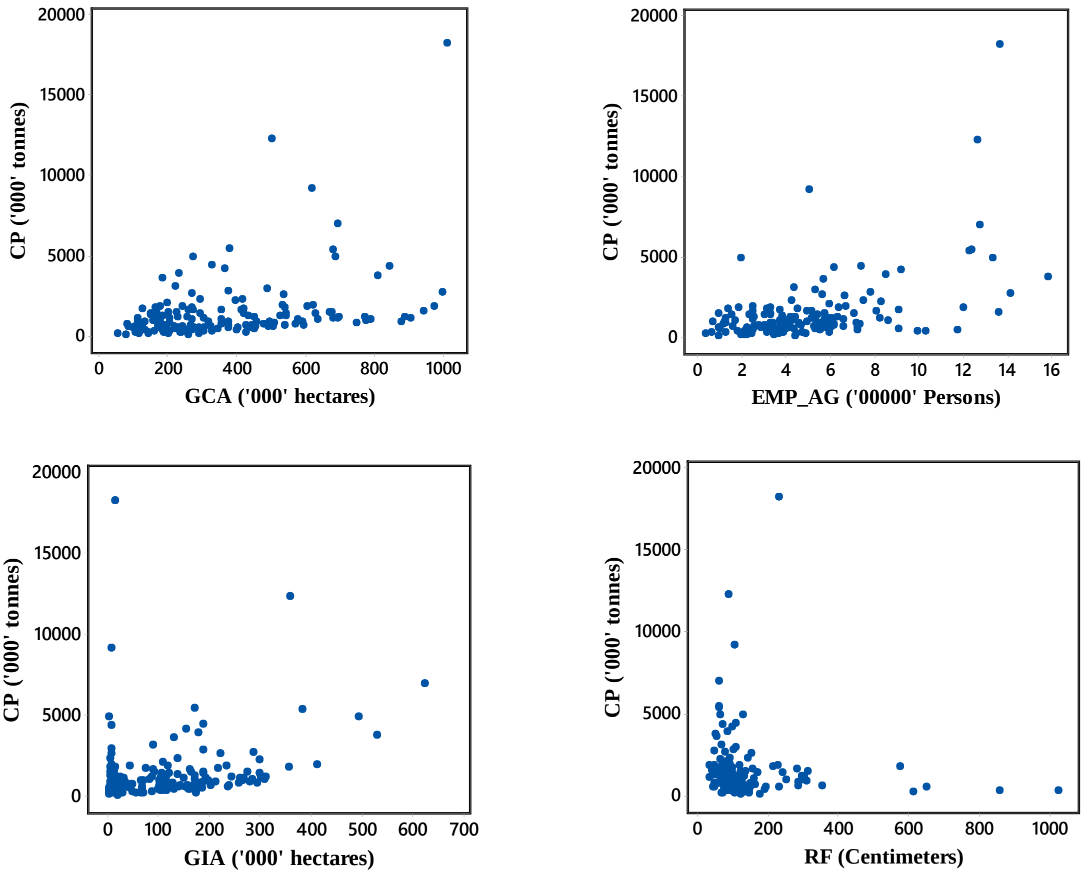


Fig. 3. Scatter plots of CP versus predictor variables

5. Model development

Freight generation is the primary step in the four-step freight demand modelling and involves the development of freight production and attraction equations to estimate the amount of freight produced and attracted to a particular zone. The relation between productions/attractions and socioeconomic variables are modelled mathematically so as to forecast future freight generations of those zones or to estimate the freight generation for a new zone with the similar characteristics. In the present study, only productions have been estimated due to lack of availability of data on freight consumptions. Out of 199 FAZs, three FAZs were left out from the modelling because of zero crop production and six were left due to unavailability of data of variable, district domestic product. The districts with zero crop production are Mumbai, Chennai and Hyderabad, the major metropolitan areas in the country. For modelling the productions for 190 FAZs, multiple linear regression with logarithmic transformations (Log-log model) and with interaction effects (Interaction model) were used. The general multiple linear regression was not able to model the present data and therefore led to development of Log-log model and Interaction model.

5.1. Log-log Model

The underlying assumptions of multiple linear regression are linear relationship between response and predictor variables, independent error terms that are normally distributed and having equal variances. However in reality, it is uncommon to encounter the data following them perfectly. Transforming the data i.e. either response variable or predictor variables or both can achieve them. In the present data, it was observed that the mean of the response variable is not a linear function of predictor variables. Also, unequal variances and non-normality were identified in the data. Logarithmic transformations are commonly applied to deal such problems. Nevertheless, here the optimal transformation for the data was found and applied. To do this, initially a power transformation on the response variable has been applied, that is, transforming the response variable by taking it to the power λ. For determining the optimal value of λ, a Box-Cox Transformation has been applied. The optimal value of λ has been found to be zero which means the transformation is natural log transformation. Hence the data have been applied with natural logarithmic transformations. Since the logarithmic transformation was applied for response variable as well as predictor variables, the model was called Log-log model. Figure 4 shows the histograms of all the predictor variables after applying transformation. It can be seen that the predictor variables are following normal distribution after transformation. The histogram of crop production after data transformation is shown in Figure 5 depicting the normal distribution.

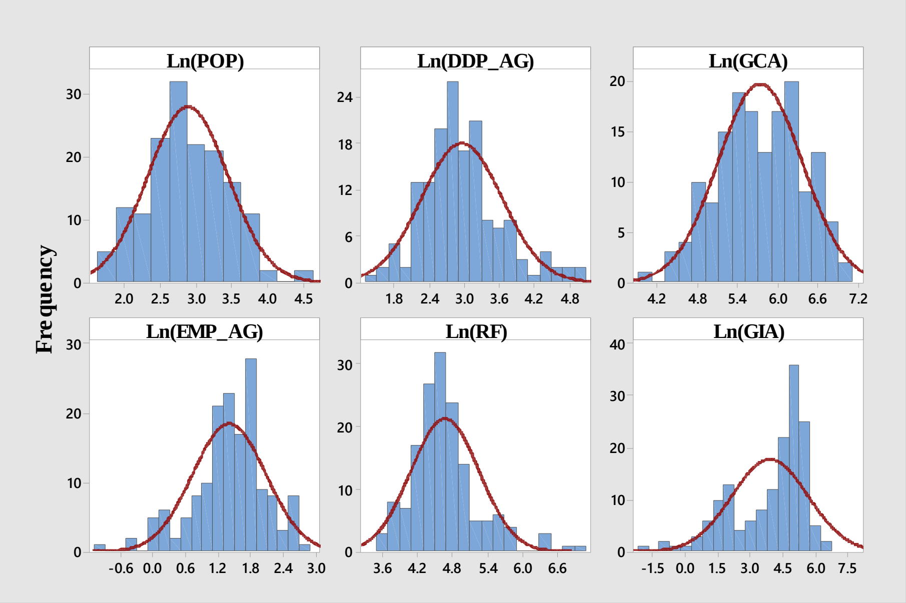


Fig. 4. Histograms of predictor variables post data transformations

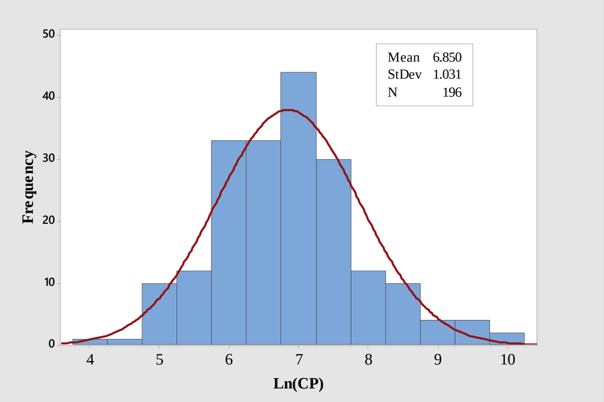


Fig. 5. Histogram of response variable CP post data transformation

Multiple linear regression was performed on the transformed data with crop production as response variable and four predictor variables population, district domestic product of agricultural sector, gross cropped area, and employment in agricultural sector. Rainfall and district domestic product were found insignificant and hence were left out from the model. Data on gross irrigated area for the state of Maharashtra were not available which comprises of 34 FAZs. Thus, even though gross irrigated area was found significant for the other FAZs for those the data were available, it was not considered in the model. Therefore, in the present model, three predictor variables were considered. The analysis of variance (ANOVA) of the model has been given in Table 3 and Table 4 gives the coefficients of the model. The significance (P-Values) values associated with F-statistic and t-statistic for population and gross cropped area indicates their significant relationship with the response variable, crop production. The variable employment was found to be insignificant but still has been included in the model since employment is an important factor influencing freight production in general. The R-square value of the model was obtained to be 0.44 whereas adjusted R-square value was 0.43. Figure 6(a) shows the standardized residuals versus fits plot which gives the information of error variances. It can be observed that the error variances are reasonably constant. Figure 6(b) shows the fit of estimated versus observed productions (Ln(CP)) and it can be observed there is a linear fit between them. The equation of the model can be formulated as in (1). This can be interpreted as: a 10 percent increase in population increases the crop production by 7.77 percent; 10 percent increase in gross cropped area increases crop production by 5.97 percent and 10 percent increase employment increases the crop production by 0.09 percent.

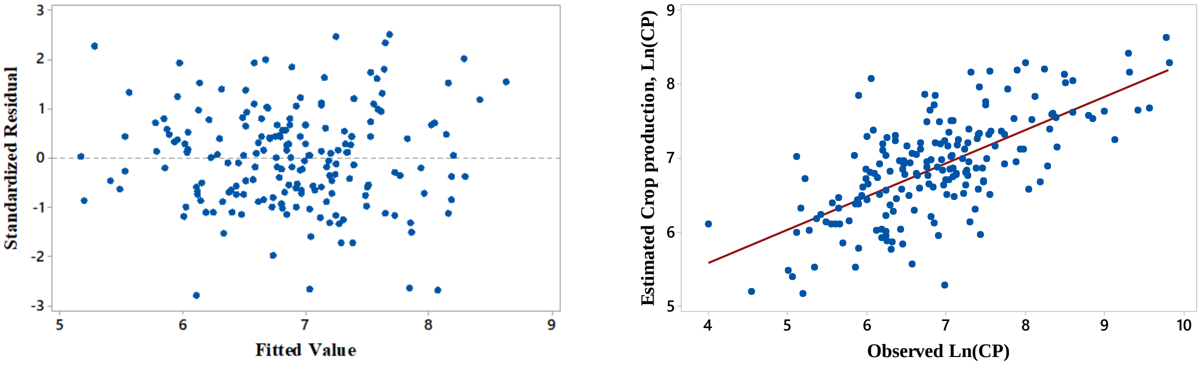
$$Ln(CP) = 1.007 + 0.786\, Ln(POP) + 0.609\, Ln(GCA) + 0.010\, Ln(EMP\_AG) \quad (1)$$

Table 3. Analysis of Variance (ANOVA) of Log-log Model.

	DF	Adj. SS	Adj. MS	F-Value	P-Value
Regression	3	88.124	29.3745	50.42	0.000
Ln(POP)	1	30.078	30.0785	51.63	0.000
Ln(GCA)	1	19.250	19.2504	33.04	0.000
Ln(EMP_AG)	1	0.005	0.0046	0.01	0.929
R-Square: 0.448			Adj. R-Square: 0.439		

Table 4. Coefficients of Log-log Model.

Term	Coef.	SE Coef.	T-Value	P-Value
Constant	1.007	0.617	1.63	0.104
Ln(POP)	0.786	0.109	7.19	0.000
Ln(GCA)	0.609	0.106	5.75	0.000
Ln(EMP_AG)	0.010	0.117	0.09	0.929



(a) (b)

Fig. 6. Graphs showing (a) Residuals Vs fitted values (b) Estimated crop production Ln(CP) Vs observed crop production Ln(CP) for Log-log Model

5.2. Interaction Model

The data considered in the study are socioeconomic variables and hence there can be a possibility of presence of interaction among them. Interaction effects are the moderated relationships between dependent and independent variable by another variable called moderator variable. If the effect of independent variable on the dependent variable varies depending on moderator variable, the interaction effect is said to be exist (Jaccard & Turrisi, 2003). The data were analysed to find out the various possible interactions between the predictors. The interaction model was developed using multiple linear regression by introducing the product terms of district domestic product and employment; population and gross cropped area; gross cropped area and rainfall. The equation of the model is as in (2). The analysis of variance of the model is given in Table 5 and the coefficients of the model are tabulated in Table 6. The significance (P-Values) values associated with F-statistic and t-statistic indicates the presence of interaction among the predictors and their significant relationship with the crop production. The R-square value of the model was obtained to be 0.53 whereas adjusted R-square value was 0.50. The standardized residuals versus fitted values plot is shown in Figure 7(a) and Figure 7(b) shows the plot of estimated and observed crop production which depicts the near linear fit between them.

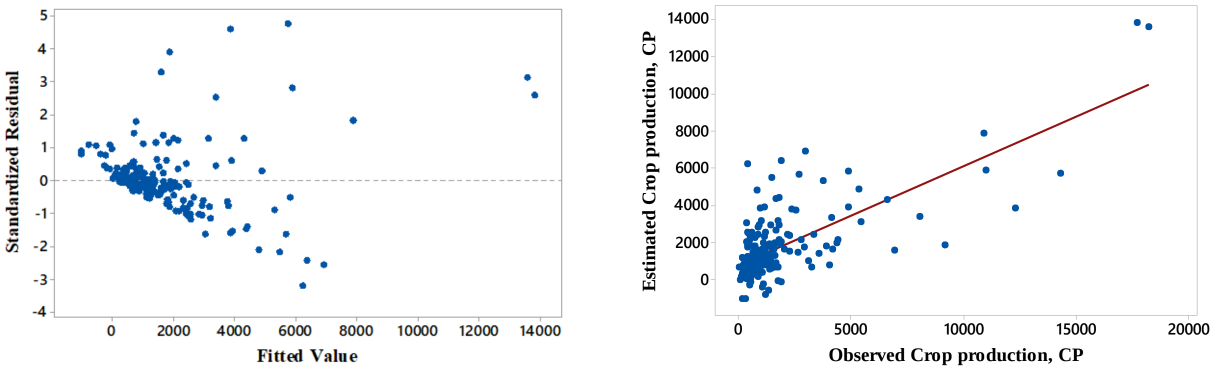
$$CP = 634 - 25.1\ \mathrm{POP} - 6.68\ \mathrm{GCA} - 5.86\ \mathrm{RF} + 27\ \mathrm{DDP_{AG}} + 189.4\ EMP_{AG} + 0.2309\ POP \times GCA + 0.03905\ GCA \times RF - 2.84\ DDP_{AG} \times EMP_{AG} \quad (2)$$

Table 5. Analysis of Variance (ANOVA) of Interaction Model.

	DF	Adj. SS	Adj. MS	F-Value	P-Value
Regression	8	729808816	91226102	25.44	0.000
POP	1	9285333	9285333	2.59	0.109
GCA	1	96306603	96306603	26.85	0.000
RF	1	31477184	31477184	8.78	0.003
DDP_{AG}	1	10391674	10391674	2.9	0.090
EMP_{AG}	1	17028587	17028587	4.75	0.031
$DDP_{AG} \times EMP_{AG}$	1	15029030	15029030	4.19	0.042
POP×GCA	1	122908855	122908855	34.27	0.000
GCA×RF	1	77616251	77616251	21.64	0.000
R-Square: 0.529			Adj. R-Square: 0.508		

Table 6. Coefficients of Interaction Model.

Term	Coef.	SE Coef.	T-Value	P-Value
Constant	634	638	0.99	0.321
POP	-25.1	15.6	-1.61	0.109
GCA	-6.68	1.29	-5.18	0.000
RF	-5.86	1.98	-2.96	0.003
DDP$_{AG}$	27	15.9	1.7	0.090
EMP$_{AG}$	189.4	86.9	2.18	0.031
DDP$_{AG}$×EMP$_{AG}$	-2.84	1.39	-2.05	0.042
POP×GCA	0.5309	0.0394	5.85	0.000
GCA×RF	0.03905	0.00839	4.65	0.000



(a) (b)

Fig. 7. Graphs showing (a) Residuals Vs fitted values (b) Estimated crop production Vs observed crop production for Interaction model

6. Discussion on Models

In this study, multiple linear regression models using logarithmic transformations and using interaction terms are developed for modelling of freight productions i.e. crop production in tonnes. Both the models have shown similar results but Interaction model has a higher R-square than Log-log model. The comparison of R-square and RMSE values of both the models are given in Table 7. The Root Mean Square Error (RMSE) of Interaction model was found to be less than the Log-log model. In Log-log model, district domestic product and employment were not found significant. However employment is an important factor influencing the freight production therefore it was considered in the model. As per the Interaction model, the impact of population on crop production is high if the gross cropped area is high and vice versa. This is because even if a district is having high population, if there is less cropped area, the production will be less. A very clear example of this case are Mumbai district of Maharashtra state and Hyderabad district of Telangana state. Likewise when the population is less but cropped area is high, the availability of labor for agricultural activities is affected and therefore results is less production. Examples of this case are Mahabubnagar district in Telangana state and Parbhani district in Maharashtra state. Similarly the impact of employment on crop production is high if the district domestic product is high and vice versa. If a district is having high domestic product but low employment, the production will be less. The impact of gross cropped area was observed to be high on production when the rainfall is high and is low with lower rainfall.

Table 7. Comparison of Log-log Model and Interaction Model

Model	R-Square	RMSE
Log-log	0.448	2290.49
Interaction	0.529	1848.33

Both Log-log model and interaction model have resulted in similar results but Interaction model showed a slight improvement over Log-log model. Even though R-square value is not very great, the estimated and observed fit of productions concludes the estimation is reasonable. These models can be improved by adding some other influencing variables such as proportion of cropped area out of total district area, types of crops which may interact with the considered variables. In freight demand estimation, there are many challenges one has to face and major among them is the data availability. For a country like India with no official data base for freight movements, it is a highly challenging task to develop freight demand estimation models at district level. Besides, reliability and accuracy of the available data is unknown. There is a possibility of presence of outliers. Since the sample size is just adequate, only critical outliers were excluded. Also, if the sample size is high, the model can possibly get improved. Above all, the models should be easy to estimate and should consider the data which can be easily available in future. Considering all these, the developed models can be considered reasonable with some improvement for modelling freight demand and can be applied for estimating future freight productions.

7. Conclusions

Freight movement plays a key role in the economic development and modelling freight transportation demand is important for policy or decision making and planning of infrastructure. India is one of the emerging nations in the world and agricultural sector in India plays an important role contributing a significant share to its economy. India is also a major exporter of many agricultural products. In the present paper, an attempt has been made to model the freight transportation demand in agricultural sector of India. The region covering eight states comprising of 199 districts was considered as the study area. Districts, the administrative divisions within the states were considered as Freight Analysis Zones for the study. The dependent variable considered was crop production in tonnes and factors affecting the production were identified as population, district domestic product of agricultural sector, gross cropped area and employment in agricultural sector and total annual rainfall. India does not have an official data base for freight movements. The data used for modelling were collected from various government websites of state and local bodies. Multiple linear regression analysis was performed using logarithmic transformations and employing interaction effects for developing the models. Both the models were compared and were found to estimate similarly. Interaction model was found to perform slightly better than Log-log model. The developed models can be used for estimating freight productions of agricultural commodities.

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