Efficiency Assessment of Major Freight Handling Areas in Case City of Jaipur, North India

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Abstract. Urban freight transport has now become an important issue in sustainable city development. Rapid urbanization and disposable income have led to rising commodity consumption in Indian cities. There are growing concerns about the impacts of urban transport on externalities and infrastructure vulnerability. While there has been a renewed focus on passenger transport, however urban freight has remained neglected in the policy discourse and plan proposal in Indian cities. Urban freight handling areas often puts considerable strain on city infrastructure with high social costs. Trade hubs and wholesale markets are major freight handling/generating areas in cities involved in urban and regional goods distribution. Freight transport infrastructure is capital intensive which requires due diligence to get maximum benefits and efficiency with overall sustainable city development. Due to scarce availability of land in urban areas there is a need for optimum usage of freight handling areas in cities.

This research paper is based on an empirical study carried out in city of Jaipur in north India. The paper presents an in-depth urban freight productivity analysis and intends to assess the efficiency in major freight handling areas in case city particularly wholesale markets using state-of-the-art benchmarking technique, Data Envelopment Analysis Technique (DEA). Primary data for operational efficiency of freight handling areas supplemented by secondary data for year 2019 is used for DEA analysis. DEA CRS based efficiency model is used for assessing the efficiency analysis of freight handling areas. Sensitivity analysis of parameters has been carried out to assess the robustness of results. The policy implications based on this study demonstrates the potential utility of DEA as a decision-making tool in urban freight sector.

Keywords: Urban Freight, Wholesale Market, efficiency, DEA, sensitivity analysis
1 Introduction

Enhancing levels of urbanization, globalization and the consumption of goods are reflected in the growing demands of logistics and transport activities. Improvements in the integrated sustainable transport systems in urban areas are required to provide the expected benefits from businesses, public authorities and the local community (Więcek & Lorenc, 2014).

It is hard to predict the outcomes of certain policy action in urban freight sector due to lack of knowledge, awareness, and diverse supply chains of goods with low level of interest among local policy makers (Lindholm, 2010). Urban goods carriers in case of Delhi city India contributes 20% of total emission and 50% contribution in PM10 emissions while having a modal share of urban goods vehicle is 3.7% only (DPCC, 2017).

The demand for logistics spaces due to rising trade volumes have pushed the distribution centers and warehouses to the periphery of metropolitan areas due the cost of land. Freight movement takes place from freight generating areas from core of city to ports for global consumption (Dablanc, Giuliano, Holliday, & Obrien., 2014). Various mitigations options are available to policy makers in their efforts to reduce the negative impacts with specific policy initiatives for urban freight transport as adopted by varies cities (Browne, Allen, Nemotob, Patier, & Visser, 2012). Several indicators in literature are described for evaluating the freight efficiency in general like: tonnage handled, population (density), urban area, road network density, freight, loading-unloading time, vehicle kilometer travelled (VKT), tons kilometres travelled, etc. (OECD, 2003).

From the indicators of the efficiency and efficiency it is possible to compare the strategic position of cities regarding the productivity and level of service for their freight handling areas. In general, efficiency and efficiency are negatively correlated, and a balance should be pursued (Chu, Lamar, & W., 1992). Infrastructure efficiency indicator is a measure of operational excellence in the resource utilization while efficiency indicators refer to the use of outputs to achieve the passenger & freight interest (Carvalho, Syguiy, & Silva, 2015). DEA is non-parametric efficiency evaluation method and widely used in efficiency of transport sector, ports, airports etc. (Markovits-Somogyi, 2011).

Measurement of the performance and efficiency of freight handling areas like wholesale markets are not much focused in India but have a major role in sustainable goods distribution in cities. This research paper evaluates the efficiency of wholesale markets in five Indian cities through Data Envelopment Analysis Method (DEA). The next section reviews literature related to DEA applications; section 3: methodology, section 4: DEA model formulation; section 5: case city profile and DMU selection, section 6: DEA efficiency analysis of freight handling areas in case cities; and the last section presents the conclusions.

2 Literature review

DEA is mostly used tool for comparing the performance of organizations with multiple variables. The literature review of DEA application reveals that this technique is widely applied for the efficiency evaluation of companies involved in transport sector. Most DEA studies covered the airports, ports, public transport companies and railways, using principally the DEA BCC and/or CCR method. The applied inputs are predominantly 3 or 4 and number of outputs is mostly 1 or 2. An extensive number of studies and variety in the nuances of application show that DEA can be employed for the assessment of decision-making units in the transport sector (Merkert & Mangia, 2014). Bootstrap-based DEA technique was used to analyze the transfer efficiencies of the subway transfer stations in Seoul (Kim, Kim, Kang, & Song, 2017). Analysis of relationship within ownership structure and technical efficiency of urban rail transit systems (URTS) by DEA reveals that, privatization has a direct and positive bearing upon enhancing efficiency of URTS (Jain, Cullinane, & Cullinane, 2008).
DEA was used to benchmark road freight companies with different operational traits. Results produced more consistent measures of goods-practice measures, compared to ratio-based key performance indicators (KPI). DEA results provides emission reduction targets for companies and an aggregate reporting tool (Holden, Xu, Greening, P., & & Dadhich, 2016). Congestion evaluation has been performed by sing three different DEA models. CCR model assessed the congestion but unable to differentiate technical efficiency with the congestion effect (Kao, 2010). DEA was used as an alternative approach to the conventional method of optimizing delivery routes for major retailer in Australia. Findings of the analysis show that, both methods give a similar outcome leading to the identical conclusion. Study recommended that routes can be rationalized by merging the less efficient stores with the more efficient ones (Lau, 2013).

Energy efficiency practices among road freight hauliers for reduction of greenhouse gases (GHG) were analysed with DEA. Study concludes that haulers are aware of the possible energy efficiency actions but lacks the knowledge and resources to fully utilize them. Energy efficiency was not important for shippers due to lack of incentives for improvement (Liimatainen, H., P., & McKinnon, 2012). Benchmarking for KPI in transport was used an instrument of government policy for heightening awareness of best practice in freight transport and potential efficiency gains un UK. Study reveals that similar distribution operations can have different energy intensity across various industry supply chains. Little attention was given to the inter-relationship with other logistical activities (McKinnon, 2009).

Efficiency of trucks involved in road construction and maintenance production processes in the Norwegian road sector was assessed by DEA method. The complexity of factors affecting performance of truck industry often leads to difficulty in determining an appropriate measure of efficiency. The input saving potential for the fleet of trucks was found to be in the range 24% to 26%, while the output increasing potential was in the range 23% to 59%. The result also shows that make & vintage of truck have no influences in their performance (Odeck, 1996). Cluster based DEA techniques were used to evaluate technical efficiency of 7365 shipping firms in Korea. Technical and scale efficiency scores for shippers were measured to identify the best-practice firms. Study suggests that optimizing non-shipping cost of delivery tends to cause firms to be smaller in size (Pattanamekar, Ki, Park, & Lee, 2011). DEA was used for efficiency measurement of four Australian and twelve other international container ports. Results revealed inefficiency is due to slack in container birth labour issues (Tongzon, 2009). DEA was used for efficiency analysis of 30 container terminal within the major ports of china and Korea for efficiency improvement and management level enhancement (BinZheng & KyuPark, 2016). DEA was used to analyse the relative efficiencies of 50 ASEAN container ports and terminals. The objective of the study was to improve the trans-ASEAN transport network and ASEAN trade competitiveness. Traditional output-oriented DEA-CCR method was applied to measures the super-efficiency (NikolaKutin, ThuyNguyen, & ThomasValléec, 2017). DEA was used for productivity analysis of 45 US commercial airports selected from the top 15 large, medium, and small airports hubs. Study reveals that small airport hubs consistently outperform the larger hubs in terms of relative efficiency (Bazargan & Vasigh, 2003).

Two-stage DEA approach was used to analyze the cost efficiency of 35 Italian and 46 Norwegian airports over time. Study suggested that in case of regional and small airports, it is the level of competition that impacts the airport’s efficiency. Military use/ownership and size of airports also have a positive impact on efficiency (Merkert & Mangia, 2014). Rough data envelopment analysis (RDEA) was used to assess the performance evaluation of furniture manufacture industry in China (Xu, Li, & Wu, 2009).

DEA method was used to evaluate the efficiency petroleum distribution facilities in the USA. Multiple inputs and outputs are incorporated into a broad set of DEA models, yielding a
comprehensive approach to evaluating supply chain efficiency (Ross & Droge, 2004). DEA was used to determine the performance levels of departments in Dokuz Eylul University (Turkey) with the technical scores and scale scores of departments to investigate main cause of inefficiency (Goksen, Dogan, & Ozkarabacak, 2015). DEA technique and its application in sustainability sector is will continue to flourish (Zhoua, Yang, Chen, & Zhu, 2018).

3 Methodology
For implementing DEA, the present paper suggests a systematic procedure of the DEA methodology in its various stages like selection of ‘decision making units’ (DMUs) to enter the analysis as well as the choice and screening of factors (Golany & Roll, 1989). The application of several DEA models is demonstrated, in order to determine relative efficiencies within the compared DMUs. This research paper assessed the efficiency measurement of five wholesale markets in Jaipur city of India.

Analysis was done using secondary/primary data on performance measures. Efficiency indicator is required for operational excellence and plays an important parameter for (local authority/policy makers) interest. The selected DMU are wholesale grain market, building hardware market, electronic market, furniture market and fruits & vegetable market in case city. Each wholesale market has different objectives and working environment. The primary data was collected and analysed for year 2019.

List of variables for efficiency analysis from literature and variables selected in this research for DEA analysis are shown in Table 1. Framework for DEA analysis for efficiency used in this study is shown in Figure 1.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Input/output variable</th>
<th>Selected variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Area of market</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>Avg size of establishment</td>
<td>✓</td>
</tr>
<tr>
<td>3</td>
<td>Avg Tonnage handled/day</td>
<td>✓</td>
</tr>
<tr>
<td>4</td>
<td>Avg shipment size</td>
<td>✓</td>
</tr>
<tr>
<td>5</td>
<td>Avg shipment frequency</td>
<td>✓</td>
</tr>
<tr>
<td>6</td>
<td>Dwell time</td>
<td>✓</td>
</tr>
<tr>
<td>7</td>
<td>Loading/unloading charges/time</td>
<td>✓</td>
</tr>
<tr>
<td>8</td>
<td>Usage of storage area</td>
<td>✓</td>
</tr>
<tr>
<td>9</td>
<td>Average length of haul</td>
<td>✓</td>
</tr>
<tr>
<td>10</td>
<td>Employment/establishment</td>
<td>✓</td>
</tr>
</tbody>
</table>

Table 1. Efficiency variables
Sensitivity corresponds to stability or robustness (W. W. Cooper, 2006). Sensitivity analysis is important to identify and its impact of DMU efficiency with respect to parameters.

There are two approaches for sensitivity analysis in DEA literature, first by adding or extracting firms (DMUs) to DEA models or by modifying the values of outputs and inputs. This research study adopts the second approach for sensitivity analysis where simultaneous proportional data perturbation of all outputs and inputs of all DMUs are involved (L. M. Seiford, 1060-1071). The outputs of efficient DMUs will all be decreased, and the inputs will all be increased by a stipulated amount of 5%. For inefficient DMUs the reverse adjustment is made. All outputs are increased, and all inputs.

4 DEA model

The DEA model can be input-oriented or output-oriented subject to the resource minimization or output maximization. This research study uses output-oriented model to assess the efficiency of major freight handling areas in case study. There are procedural issues relating to variables which need to be examined before applying DEA. Some of these issues are homogeneity of units, selection of input/output variables, measurement of variables and their weights. Each of these issues can present difficulties in DEA analysis. (R.G.Dyson, R.Allena, A.S.Camanho, V.V.Podinovski, C.S.Sarrico, & E.A.Shalea., 2001)

In DEA, the productivity of a unit is evaluated by comparing the amount of output(s) produced in comparison to the amount of input(s) used. This method has been widely applied for the evaluation of a multitude of decision-making units (DMUs) in various fields, e.g. in agriculture, in banking sector and in the health industry as well. As it can measure the efficiency of multiple input-output production units, it has also been widely employed in the transport sector. The term DMU was used to allow for the model’s application to a wide variety of activities (Charnes, Cooper, & Rhodes, 1978) & (Farrell., 1957).
4.1 Efficiency ratio

Efficiency is the ratio of the outputs produced with respect to amount of inputs used. DEA measures the efficiency of a unit (called Decision Making Units or DMU) using a weighted ratio as illustrated in equation (1) below:

\[
\text{performance} = \frac{\text{virtual output}}{\text{virtual input}} = \frac{u_1y_1 + \cdots + u_my_m}{v_1x_1 + \cdots + v_mx_m}
\]

Where:
\(x\) and \(y\) are resp. the input and output vectors and \(u\) output\'s weight, \(v\) input\'s weight.

In DEA, the performance of a DMU is always calculated by comparing it to the efficiency frontier directly determined from the data. Two basic models of DEA are; the CCR model with constant returns to scale (Charnes, Cooper, & Rhodes, 1978), and the BCC model with variable returns to scale (Banker, Charnes, & Cooper, 1984).

4.2 The CCR (Charnes, Cooper and Rhodes) model

The CCR model is one of the original DEA model based on constant returns to scale. One basic characteristic of the CCR model is the multi-output and multi-input reduction to a single (weighted) input and output combination for each DMU. The original CCR DEA model utilizes linear programming to produce an efficiency measure for a DMU, requiring only that the DMUs convert similar inputs to similar outputs and that these can be quantified. Single DMU performance in comparison facilitates a ranking of the different analyzed DMUs. It scales their relative efficiency from low to high, whereby the last one is defined as 100% efficient. The CCR model contains both mathematical maximization and minimization problems (Charnes, Cooper, & Rhodes, 1978).

4.3 BCC model

The BCC model is an extension of the CCR model, which investigates variable returns to scale. The mathematical formula for the BCC model is quite similar to that of the CCR model, except for an additional variable. In BCC model there is proportional change for input and output variables, and it is on increasing or decreasing returns to scale (Banker, Charnes, & Cooper, 1984).

4.4 Outputs from DEA model

This research study uses the frontier analyst software® for DEA analysis. Outcome results of DEA model are efficiency score of DMU, Lambda value, lambda peer indicator and return to scale (RTS). The Lambda Values are the raw weights assigned having value of output zero (no peer) or as a cell reference to the peer value relates to. Lambda value is associated with the peer indicator. RTS gives information about the returns to scale where -1 indicates decreasing returns to scale, 0 indicates constant returns to scale, and +1 indicates increasing returns to scale. Efficiency Score of the item is expressed as a percentage (Frontier Analyst, 2019)

5 Case cities profile & market selection
Jaipur is capital city for the state of Rajasthan in India. The city is major attractor of tourists and major hub for handicrafts, gems, jewelry, die printing (textile) and stone crafting. It is situated in north eastern part of Rajasthan, 280 Km from Delhi. Jaipur extents to an area of 2939 sq.km in which walled city (old area) constitute 17 Sq.km, 281 sq. km under Jaipur municipal corporation and rest is 2650 sq.km under Jaipur development authority. Total population of Jaipur city is 3.05 million (yr. 2011). Decadal growth rate of Jaipur city is +35%. Gross population density of Jaipur is 64 PPH and workforce participation rate 34.7% (JDA, 2019). As per Jaipur master plan of year 2011 residential land use constitutes 44.8% (13825 ha), commercial 6.7% (2064 ha), industrial 6% (1862 ha), governmental 2% (602 ha), mixed land use 3.3% (1034 ha), public & semi-public 10.5% (3241 ha), recreational 11.3% (3461 ha) and circulation 15.4 % (4741 ha).

Some of the major wholesale markets in Jaipur are shown in Table 2. Nature of goods distribution of these wholesale markets varies from commodity to commodity. Some of these markets have goods distribution in urban areas only like furniture, dairy and meat products. Some of the markets have more regional distribution of goods like industrial products, chemical and fertilizers. Some markets have both urban and regional goods distribution like textile and handicraft (JDA, 2019).

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Commodity</th>
<th>Market location</th>
<th>Distribution type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Food grains</td>
<td>Surajpole, Kukasheda</td>
<td>U &amp; R</td>
</tr>
<tr>
<td>2</td>
<td>Fruits &amp; vegetables</td>
<td>Muhana, Lal Kothi</td>
<td>U &amp; R</td>
</tr>
<tr>
<td>3</td>
<td>Diary &amp; meat products</td>
<td>Malviya Nagar, NH11 bypass</td>
<td>U</td>
</tr>
<tr>
<td>4</td>
<td>Textile</td>
<td>Sanganer, Walled City</td>
<td>U &amp; R</td>
</tr>
<tr>
<td>5</td>
<td>Construction material</td>
<td>Aatish market, Chandpole</td>
<td>U</td>
</tr>
<tr>
<td>6</td>
<td>Electronics</td>
<td>Jayanti market</td>
<td>U</td>
</tr>
<tr>
<td>7</td>
<td>Handicrafts</td>
<td>Walled City</td>
<td>U &amp; R</td>
</tr>
<tr>
<td>8</td>
<td>Pharmaceuticals</td>
<td>Walled City</td>
<td>U</td>
</tr>
<tr>
<td>9</td>
<td>Chemical &amp; fertilizers</td>
<td>Durgapur</td>
<td>R</td>
</tr>
<tr>
<td>10</td>
<td>Industrial products</td>
<td>Vishkarma Industrial Area</td>
<td>R</td>
</tr>
<tr>
<td>11</td>
<td>Furniture</td>
<td>Sitapura</td>
<td>U</td>
</tr>
</tbody>
</table>

Source: (JDA, 2019) (U-Urban Distribution, R-Regional Distribution)

There is very little importance attached to the characteristics, problems and potentials of goods movement within urban areas in present state-of-the art of city planning and practice in India. A total of five major wholesale markets are selected as DMUs in case city of Jaipur India, for efficiency analysis. The Brief characteristics of these wholesale markets in case city is mentioned in Table 3.

### 5.1 Input/output parameters for infrastructure efficiency

Selected input and output parameters for infrastructure efficiency of wholesale markets in case cities are shown in Table 3. It is observed that weekly tonnage handled in across wholesale markets varies from 5.8 tons to 24.8 tons in Jaipur case city. This suggests that building hardware goods distribution is more involved in intercity and intra city distribution compared to other wholesale market in Jaipur city.

<table>
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</tbody>
</table>

Table 3. Input/output parameters for operational efficiency of DMUs
It is observed that weekly tonnage generated per square meter by building hardware market is highest followed by grain market, fruits & vegetable market. Furniture market is generating least weekly tonnage per square meter of area followed by electronics market due to inherent nature commodity.

6 Performance analysis using DEA

CRS efficiency score of wholesale markets (DMUs) for their operational efficiency is shown in Table 4. Furniture market has least efficiency score (11%), followed with grain market (32%), fruits & vegetable market (33%) and electronics market (58%). Building hardware market got the most efficient score of (100%) inefficiency.

Table 4. Operational efficiency score of wholesale markets

<table>
<thead>
<tr>
<th>DMU No.</th>
<th>DMU Name</th>
<th>CRS Efficiency</th>
<th>Sum of lambdas</th>
<th>Return of scale (RTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Furniture market</td>
<td>11%</td>
<td>0.059</td>
<td>Increasing</td>
</tr>
<tr>
<td>2</td>
<td>Grain market</td>
<td>32%</td>
<td>0.192</td>
<td>Increasing</td>
</tr>
<tr>
<td>3</td>
<td>Building hardware</td>
<td>100%</td>
<td>1.000</td>
<td>Constant</td>
</tr>
<tr>
<td>4</td>
<td>Fruits &amp; vegetable</td>
<td>33%</td>
<td>0.104</td>
<td>Increasing</td>
</tr>
<tr>
<td>5</td>
<td>Electronics</td>
<td>39%</td>
<td>0.074</td>
<td>Increasing</td>
</tr>
</tbody>
</table>

Sensitivity analysis of operational efficiency for wholesale market is shown in Table 5. Efficiency score of building hardware market remains stable whereas efficiency of other markets increased. Fruits and vegetable market observed maximum increase in efficiency score by 8%.
Table 5. Sensitivity analysis of operational efficiency

<table>
<thead>
<tr>
<th>DMU No.</th>
<th>DMU Name</th>
<th>CRS Efficiency</th>
<th>Sum of lambdas</th>
<th>Return of scale (RTS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Furniture market</td>
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<td>Constant</td>
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<tr>
<td>4</td>
<td>Fruits &amp; vegetable</td>
<td>41%</td>
<td>0.104</td>
<td>Increasing</td>
</tr>
<tr>
<td>5</td>
<td>Electronics</td>
<td>47%</td>
<td>0.074</td>
<td>Increasing</td>
</tr>
</tbody>
</table>

7 Conclusion
This paper presents a DEA approach to assess the efficiency of wholesale markets in Jaipur city in north Indian. It is observed that relative efficiency scores generated through DEA method can be used for ranking and efficiency of wholesale markets. This study considered different set of inputs and but same output variable for efficiency analysis.

It is observed that building hardware market is most efficient with having efficiency score of 100% in comparison with all other wholesale markets. Furniture market has least efficiency score of 11%. Results observed from Sensitivity analysis confirm improvement in operational efficiency score with marginal perturbation of in-input variable with respect to most efficient DMU. Observed improvement in efficiency score of wholesale markets remains in range of 7%-8%, except furniture market (3%) in sensitivity analysis.

There is need to assess the performance levels of different wholesale markets across various cities of India to widen the scope and accuracy of benchmarking in future scope studies.

References


