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Evaluation of Warehouse Performance: Case of Unaccompanied Personal Baggage (UPB) Warehouses in Sri Lanka

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1. Introduction

In a competitive environment where warehouses seek to outperform their competitors, it is critical to measure warehouse efficiency which provides warehouse managers with a clear vision of current issues and opportunities for improvement. Under bonded warehouses there are a separate kind of warehouses known as UPB warehouses (unaccompanied personal baggage warehouses). Customs bonded baggage warehouses are situated in Colombo, Peliyagoda, Wattala, Kandy, Galle, Kurunegala, Addalachchena, *et cetera* to clear unaccompanied baggage sent before departure from a foreign country. The core objective of this study is to measure and critically evaluate the level of efficiency of such UPB warehouses with reference to the three warehouses of ABC (PVT) LTD. Although there exist UPB sector warehouses throughout the island, no previous study has measured the efficiency levels of such warehouses.

2. Literature Review

Warehouses commonly use resources such as equipment, labour and investment to provide a service to customers according to their needs. Although single factor metrics are easy to calculate and easy to understand they are not the best choice to measure the warehouse performance. Charnes et al. (1978) display fractional programming as an extension to Ferrell's single productivity efficiency measure to solve and measure the efficiency when there are multiple inputs and outputs [1]. This technique is called DEA (Data Envelopment Analysis). DEA identifies the most efficient decision making unit and measures the efficiency based on the deviation from the efficient decision making unit. In order to correct the problems and inefficiencies of single factor performance measures and to compute the efficiency of warehouses accurately a system based measure of operational efficiency [2] was developed by Hackman, et al. (2001) which is an input-output based model. It is an extension of the DEA method by Charnes, et al. Also, Hackman, et al. have identified the inputs as labour, space and equipment and the outputs used are the movement, storage and accumulation. Even though Hackman's model was a breakthrough in measuring the efficiency of warehouses and benchmarking it is incomplete in that it does not include the aspect of information technology. Due to this, another model was created including the information technology aspect. Hamdan & Rogers (2008) extended the model developed by Hackman et al, overcoming the shortcomings of the latter [3]. The Hamdan & Rogers model considered labour, space, technology investment and material handling equipment (MHE) as inputs and shipping volume, order filling and space utilisation as outputs of the model.

3. Methodology

In order to develop the empirical model, Charnes, et al., is taken into consideration. The objective here is to obtain weights (V_i) and (U_i) that maximize the ratio of DMUo (Decision Making Units) being evaluated.

In a similar study DMUo is considered as (o = 1, 2, 3…n). Hamdan & Rogers adopted the fractional program

$$(FPo)\ Max\ \theta = \frac{u_1 y_{1o} + u_2 y_{2o} + \dots + u_s y_{so}}{v_1 x_{10} + v_2 x_{2o} + \dots + v_m x_{mo}} = \frac{\sum_r u_r y_{ro}}{\sum_i v_i x_{io}}$$

$$\frac{u_1 y_1 + \dots + u_s y_{so}}{v_1 x_{1o} + \dots + v_m x_{mo}} \le \frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \le 1 \text{ for } j = 1\dots n,$$

$$v_1, v_2 \dots v_m \ge 0 \text{ for } i = 1\dots m,$$
$$u_1, u_2 \dots u_m \ge 0 \text{ for } r = 1\dots s,$$
($\sum V_i$ can't be equal to zero)

where θ is the objective function value that maximizes the ratio of DMUo, which is also called the 'relative efficiency score', V_i the weight for input i, U_r the weight for output r, X_{io} the value for input x of DMU_o and Y_{ro} the value for output y of DMU_o.

Hamdan & Rogers replaced this fractional equation with a linear equation (LPo)

$$\text{LPo Max } \theta = \sum_r u_r y_{ro}$$

$$\text{Subject to } \sum_i v_i x_{io} = 1$$

$$\sum_r u_r y_{rj} - \sum_i v_i x_{ij} \le 0 \text{ for } j = 1\dots n,$$

$$v_1 \ge 0, u_r \ge 0 \qquad \text{for } i = 1 \dots m,$$
$$\text{for } r = 1 \dots s.$$

As explained by Hamdan & Rogers in their findings, in order to obtain the relative efficiency scores, θ *, this linear program must run n times, and the optimal solution of the above linear program (LPo) is represented by (y*, v*, u*), where v* and u* are the optimal weights for each DMU, and y* is the relative efficiency score of the DMUs.

3.1. Formulation of the restricted DEA (Data Envelopment Analysis) model

A measurement framework can be used to identify the input and output variables, and weight restrictions can be set according to the mission and the objectives of the organisation (Allen, et al., 1997) [4]. In a similar study, in order to apply weight constraints, the direct restrictions on the weights of some or all of the inputs and outputs method proposed by Allen, et al. (1997) is adopted by Hamdan & Rogers (2008).

The additional constraints were determined using a heuristic approach by aligning expert opinions and strategic thinking (Hamdan & Rogers, 2008)

$$0.21 \leq \frac{v_1}{v_2} \leq 4.891$$

(V_2, V_4 can't be equal to zero)

$$0.18 \leq \frac{v_1}{v_4} \leq 3.93$$

The above constraints were identified by Hamdan & Rogers. In these constraints V_i refers to weight for input 'i'. Therefore, it was reasonable to use the same level of restriction on weight in this study to measure the efficiency level. As a result, weightage of inputs in this study is the same as the restriction set by Hamdan & Rogers as the inputs used in both studies are identical. The unrestricted DEA model proposed by Charnes, et al., allows the DMU's to choose the weight restrictions of their inputs and outputs in order to maximize their efficiency level. Due to this reason the unrestricted DEA model will assign unreasonably low or unreasonably high weights when measuring the efficiency scores.

3.2. Variables included in the study

As per the model adopted by the researcher, inputs and outputs used by Hamdan & Rogers has been adopted while developing the model for this study.

Table 1: Variable measuring units

	Variable	**Measuring Unit**
Inputs	Labour	Total annual man hours
	Space	Total warehouse square feet
	Technological investment	Total annual cost for technology
	MHE cost	Total annual cost for MHE
Output	Throughput	Total annual boxes shipped

3.2.1. Inputs

Labour: The total direct man hours spent on activities related to warehousing functions are taken into consideration. The total employees in the respective warehouses were counted and the total working days of the employees during the financial year of 2015/16 and 2016/17 were taken into consideration.

Space: The total square footage of the warehouses are taken into consideration.

Technological Investment: The total annual cost of technology department which supports warehouse operation was taken into consideration.

Material handling equipment cost: The total cost incurred for the MHE.

3.2.2. Output

Throughput: Is measured by units such as boxes, pallets etc. which are being shipped out of the warehouses during the financial years of 2015/2016 and 2016/17.

The secondary data used in this study was collected from a homogenous set of 3 warehouses under the same UPB operator ABC (PVT) LTD in Sri Lanka during the financial year of 2015/16 and 2016/17 and it is analysed using data envelopment analysis method.

4. Results

The unrestricted efficiency score of the warehouses for the financial year of 2015/2016 and 2016/2017 are displayed in the below Table 2.

Table 2: Unrestricted DEA model efficiency scores 2015/16 and 2016/17

DMU	Efficiency Score 2015/16	Efficiency Score 2016/17
WH1	1	1
WH2	1	1
WH3	0.906	0.917

As given in Table 2, according to the efficiency scores of the unrestricted DEA model the warehouse 1 and 2 are considered to be efficient in both financial years as their efficiency score is 1; it satisfies the DEA condition that in order for a DMU to be efficient its efficiency score should be $\theta = 1$.

The efficiency scores of warehouse 3 for the two financial years of 2015/2016 and 2016/2017 are 0.906 and 0.917 respectively. It is considered to be inefficient because it does not meet the DEA efficiency criteria of $\theta = 1$.

Table 3: Restricted DEA model efficiency scores 15/16 and 16/17

DMU	Efficiency Score	Efficiency Score
WH1	1	1
WH2	1	1
WH3	0.626	0.614

As depicted by Table 3 warehouses 1 and 2 are efficient in the restricted DEA Model as the efficiency scores are equal to 1. The efficiency score of warehouse 3 for the financial years of 2015/2016 and 2016/2017 are 0.626 and 0.614 respectively. Both results don't meet the criteria of DEA efficiency as the efficiency scores are less than 1.

5. Conclusion/Recommendation

Warehouse function is very crucial within any supply chain. Therefore, it is important to measure the performance of warehouses using key indicators such as efficiency. Although this study was based on the three UPB warehouses of ABC (PVT) Ltd the recommendations given out to the inefficient warehouse among the three warehouses can be used to reduce the inefficiencies in other homogenous warehouses as well. Warehouses 1 and 2 are efficient in the restricted DEA Model as the efficiency scores are equal to 1. Warehouse 3 is inefficient mainly due to excess levels of inputs compared with the output amount. It is crucial for a warehouse to keep the inputs in this case labour, warehouse size, technological investments and material handling equipment cost under the required level. Otherwise it will cause inefficiencies. One of the reasons for warehouse 3 to be inefficient is its excess man hours per financial year. The warehouse doesn't get an equal number of cargo all thorough out the year. The amount of cargo handled in the peak periods of the year (April, December) are higher than the rest of the year, therefore a large work force is not required throughout. A small team of employees to carry out activities should be hired on permanent basis and on peak periods laborers from man power agencies can be hired additionally. This would reduce the annual man hours as a large work force is only used during peak periods. Another reason for inefficiency is the excess cost incurred for material handling equipment. According to the management of ABC (PVT) LTD there are three forklifts which are operating at warehouse 3. As it only handles about 60000 boxes as an average per year it is a question whether three forklifts are needed for the process. In order to reduce the material handling equipment cost, it is crucial to reduce maintenance costs of equipment. Steps which can be taken in this regard include the use of preventive maintenance to avoid equipment failure, and investment in expert staff having specialised knowledge of equipment and predictive maintenance. Additionally, in order to make warehouse 3 efficient it is necessary to reduce technological investment incurred in the warehouse. This can be done by standardising equipment, software platforms and configurations, as well as outsourcing key IT functions such as technical support, data storage and back-up.

References

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