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# ASSESSING THE SUSTAINABILITY OF MEAT TRANSPORT MODE CHOICES IN ABATTOIR LOGISTICS USING THE ANALYTIC HIERARCHY PROCESS

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**ABSTRACT**

This paper is an attempt to review the compliance of abattoirs in developing country cities to global sustainability requirements. Some unsustainable abattoir operations in developing country cities, as it relates to logistics and meat transport, have been discussed and their implications were identified. The study disclosed how poor meat quality could be as a result of bad choices in the mode of transportation and distribution of the meat. Four modes were identified, considered and compared in this review and they include; pedestrian carriage, motorcycles, open vans, and refrigerated cooling vans. To ensure that the triple bottom line of sustainable development was met, meat safety/hygiene, reduced transport cost, reduced $CO_2$ emissions, and reduced stress on labourers were the four major performance indicators used in the assessment of the efficiency of each mode. Using the Analytic Hierarchy Process (AHP), the sustainability of the four modes were assessed systematically and simultaneously. The paper strongly recommends the refrigerated cooling van as the best mode option for meat transport, with benefits up to 40% above each of the other modes.

**Keywords:** abattoir, analytical hierarchy process, logistics, meat, mode choice, sustainability.

## INTRODUCTION

The abattoir sector has been neglected in most national livestock development programmes of most developing countries. Increase in consumer concern for improved meat safety is driving the pressure on governments to initiate substantial hygienic improvements. This has activated a significantly increasing interests, among different stakeholders, in rehabilitating abattoirs for ruminants, pigs and other red meat-producing livestock in such a way that will be hygienic to the consumers, profitable to the abattoir operators and meat marketers, accessible by the society, and above all bearable and sustainable to the environment. Abattoir operations are meant to recover the edible portions of slaughtered animals and make them available for human consumption (Fearon, Mensah, and Boateng, 2014). This makes the abattoir a key sector in the food industry. A holistic intervention has not been made in the abattoir sector in many developing countries despite the fact that many food and drug laws/guidelines exist in such countries with requirements that both imported livestock products and locally produced ones must meet (Makwe and Chup, 2013). Several investigations into the hygienic standards of meat sold in developing countries have been made by researchers at different locations and at different time periods with myriads of reasonable recommendations, yet over the years, the result has been a minimal and/or even decreasing performance in some city locations (Fearon, Mensah, and Boateng, 2014; Makwe and Chup, 2013; Frimpong *et al*, 2012). Movement of the meat within and outside the abattoirs plays a key role in ensuring sustainability in the sense that it is an important consideration when assessing the efficiency of the abattoir operations in meeting the societal demand for a healthy meat, operational demand for a profitable business, and global demand for environmental sustainability. Bowater (1996) outlined four important factors that should be considered in meat preparation and transportation with emphasis on chilled meat, and these factors include; shelf life, tenderness, taste, and appearance. According to his report, the shelf life of a meat product is directly related to how hygienically it has been prepared and transported and this has a direct implication on human health beyond the other three factors.

The definition of Sustainable Development as "the development which meets the needs of the present without compromising the ability of the future generations to meet their own needs" (Brundtland, 1987) is holistic, despite some attending controversies. It attempts to summarise all that a sustainable system in a sustainable society must stand for, and abattoirs are no exceptions. In a nutshell, a sustainable abattoir is, therefore, the one that meets the economic, social, health, and environmental needs of both its immediate and global society while operating under consciously predetermined framework that ensures future efficiency and effectiveness.

The focus of this review is on developing country cities for three major reasons. First, over 40% of the average population of these countries live in the cities with the figure as high as 60% in some countries like Libya, Botswana, Gabon, and South Africa (Geohive, 2010). Secondly, the city abattoirs also supply nearby rural dwellings. And thirdly, some abattoirs in the cities export their products for foreign exchange due to their nearness to

the sea ports. Hence, the definition above concisely gives what a sustainable abattoir should be. It emphasises the fact that abattoirs in developing country cities must rise up to the global sustainability challenge in ensuring a high relative contribution to the nations' revenue while maximising the operators profit, creating more gainful employment for the teaming population, and above all ensuring that the meat is available and affordable with strict compliance to health standards and controlled emission of greenhouse gasses. The question remains, how well have the abattoirs in developing countries complied with the set out requirements and how better can they perform? Especially in the aspects of meat distribution and transportation.

Contaminated meats have been seen as the major cause of food poisoning in most countries of the world. Research by Adzitey *et al* (2010) shows that samples of all the meats from shops at Tamale, Northern Ghana were all contaminated with microbial (staphylococcus spp., streptococcus spp., enterococcus spp., Salmonella spp and Escherichia coli) food borne infections. This is identical to the findings of Amaechi, and Ezeronye (2006) from there research conducted in Umuahia, Abia State, Nigeria. This is already a present threat how much more the future. Such results leads to a great discrimination among meats, and decreased patronage. Which is indirectly an economic threat. This phenomenon could have been as a result of several factors but the manner in which fresh meats are handled and transported from the abattoirs to the markets should have been a major contributor.

## ABATTOIR LOGISTICS

Abattoir logistics involves the management of the movement of the animals to the abattoir as well as the flow of the meat between the abattoir and the market till it gets to the consumers. This is done in such a way as to meet some requirements of all the stakeholders involved (Ljunberg, Gebresenbet, and Aradom, 2007). Gebresenbet *et al* (2011) investigated into how the time spent during meat distribution affects meat quality and the environment. In an optimisation analysis of large and small scale abattoirs in relation to animal transport and meat distribution, they demonstrated how small scale abattoirs located in different areas of a city can be more sustainable than fewer large scale ones. This would be as a result of reduced cost and vehicle emissions for transporting the meat over short distances and could also be as a result of less handling required for a meat to get to the market. Some good logistic chains already exists in majority of the developing country abattoirs as disclosed by Frimpong *et al* (2012), but enough emphasis has not been laid on the nature, type, and condition of the vehicles with which the meats are being distributed. The interest of this paper is to address the mode choice related issues of meat hygiene and general sustainability of meat distribution. Some of the available and used modes for meat transport in developing countries include; buses, vans, open-carriage vans, cars, motor cycles, bicycles and pedestrian carriages.

The logistic chain can be categorised into three phases - the 'into' phase, the 'within' phase and the 'out-from' phase. The first phase involves the movement of the animals from the farm to the abattoir, the second phase involves the movement of the animals within the abattoir until their slaughter, and the third phase involves the movement of the carcass (meat) from the abattoir to the market. In some few cases there are abattoirs keeping their own animal farms as part of their operations, but yet it is difficult to see one that entirely depends on their own farm for all the meat demanded, making most abattoirs dependent on other farmers for a daily supply of livestock. This shifts the responsibility of the 'into' logistics from the abattoir operator to the farmer and the merchants. Assuming that the abattoirs comply with the necessary animal inspection policies of the Food and Agricultural Organisation (FAO) of the United Nations which aims at providing safe and wholesome meat for human consumption, it would be then reasonable to submit that the out-from logistics could be more responsible for the deteriorating meat security. Herenda *et al* (2000) summarised the FAO two fold objectives of meat inspection as: 1, ensuring that only apparently healthy, physiologically normal animals are slaughtered for human consumption and that abnormal animals are separated and dealt with accordingly; 2, ensuring that meat from animals is free from disease, wholesome and of no risk to human health. The issue is not just within the abattoir, but extending this conscious carefulness to the transportation of the meat away from the abattoir till it gets to the consumers. Figure 1 below is a simple illustration of this movement of animals to and from the abattoirs.

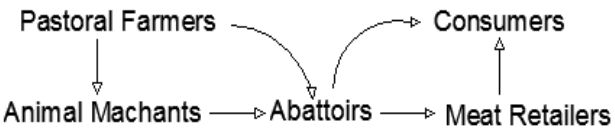


**Figure-1.** Abattoir logistics pattern in developing countries.

As the meat is the major end product of the abattoir operations, several factors relating to the transportation of meat from the abattoir, come into play in ensuring the safety, hygiene, profitability, and promptness (timely arrival to the retail market) of meat. The factors include, the mode of transport, the time of opening, the qualification and experience of transporters and meat handlers, among other. Of all these, the transportation mode has a stronger impact on meat movement. The reason for this is that it points more strongly and

significantly to the key sustainability indicators under consideration.

## METHODOLOGY: THE ANALYTIC HIERARCHY PROCESS

This method was introduced by Thomas Saaty in 1980 and it is has been an effective tool for dealing with complex decision making (Saaty, 1997) like choosing the most sustainable mode of transport for abattoirs in developing country cities. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP helps to capture both the subjective and objective aspects of a decision. In addition, it incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process. The process involves using a set of evaluation criteria and iterative options to optimise for the criterion which achieves a trade-off among different criteria.

The AHP generates a weight for each evaluation criterion according to the pairwise comparisons of the criteria. The higher the weight, the more important the corresponding criterion. Next, for a fixed criterion, a score is assigned to each option according to the pairwise comparisons of the options based on that criterion. The higher the score, the better the performance of the option with respect to the considered criterion. Finally, the combined criteria weights and options scores are used to determine a global score for each option, and a consequent ranking. The global score for a given option is a weighted sum of the scores it obtained with respect to all the criteria. There was an attempt to ensure that the environmental, health, cost, and societal considerations are reflected in the analysis, while keeping it simple and concise.

## ANALYSES AND DISCUSSIONS

### The predominant modes

Several modes of transport exist for moving meat from the abattoir to the retail market in developing country cities. Four predominant options are considered in this case and they include;

a) **Pedestrian carriage;** In Most developing countries, retailers of different categories of meat visit the abattoir on daily bases with cotton sacks, polythene bags, steel basins and plastic basins to buy different proportions of meat for their daily sales. This they carry on their heads or drag with their hands or push with wheel barrows from the Abattoir to the market then displays on wooden and steel tables for sales from morning till twilight.

b) **Motorcycle;** To spear them the heavy load of head/hand carriage, some retailers use motored two wheeled rides to carry the meats (Bicycles are not frequently used due to the loads involved).

c) **Open vans;** This represents four wheeled automobiles with open carriages. The marketers either own or higher them for the purpose of meat carriage. Some abattoirs also own them for their supply and distribution. Sometimes the marketers are seen on the back of the vehicles loaded with meat, seating on the meat. At some times they seat on the van frames with their legs matching the meat on their way to the market.

d) **Refrigerated cooling van;** This represents all three axle to four axle covered vans with refrigeration. They have restricted quantity of meat per trip, specified time of departures, and specified route of distribution coverage.

### The sustainability indicators/Factors for abattoir logistics

Performance indicators are necessary for the assessment of the sustainability of the available meat transport modes. Indicators are parameters, or values derived from parameters, which describes the state of a phenomenon or a system, either fully or partially, with significance extending beyond that directly associated with the parameter values (OECD, 2003). They play two major roles in sustainability analysis: reducing the amount of data required to describe a situation fully and facilitating communication with diverse audiences (keirstead, 2007). The indicators used for this review, were selected based on the series of processes outlined by Maclaren (1996) as well as Li and Xulin (2013).

Four major indicators or factors were identified for sustainable meat movement. In their order of perceived relative importance, they are; assured meat safety/hygiene, reduced cost of transportation, reduced amount of $CO_2$ emissions and reduced stress on labourers.

### The AHP; Step by step iteration

The iterative and quantitate process involved in the implementation of the AHP can be summarised into three consecutive steps:

a) Computing the vector of criteria weights

b) Computing the matrix of option scores and

c) Ranking the options (Coyle, 2004).

These steps will be followed illustratively as a guide to the designers and planners of abattoir logistics regarding how to inform sustainable decision making.In order to compute the weights for the four different criteria; a pairwise comparison matrix will first be created. It is a 4 x 4real matrix because four evaluation criteria have been chosen for consideration. Each entry of the matrix

represents the importance of the row criterion relative to the column criterion. The guide to the weight selection is summarised in the Table-1 below as reproduced from Coyle (2004).

Based on this guideline, the factors were weighted as shown in the Table-3. The nth roots of each factor are calculated by multiplying each row and rising to the power of the reciprocal of the number of factors considered.

$$\text{Nth root} = \prod_1^{nj} a_{ij} \quad (1)$$

Where a is the weighted score of factor in row i for n number of factors in column j.

The matrix of eigenvectors shown is the ratio (proportion) of the nth value of each criterion. It is referred to as the Relative Value Vector (RVV) and it is given by the expression;

$$\text{RVV} = \frac{nth\ root_i}{\sum_{j=1}^{j=n} nth\ root_i} \quad (2)$$

It will be important to note here that a good computed RVV will sum up to unity (Saaty, 1997).

**Table-1.** Weight selection criteria for AHP.

| Intensity of importance | Definition | Explanation |
|---|---|---|
| 1 | Equal importance | Two factors contribute equally to the objective |
| 3 | Somewhat more important | Experience and judgement slightly favour one over the other. |
| 5 | Much more important | Experience and judgement strongly favour one over the other |
| 7 | Very much more important | Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice |
| 9 | Absolutely more important | The evidence favouring one over the other is of the highest possible validity |
| 2,4,6,8 | Intermediate values | When compromise is needed |
| | (Coyle, 2004) | |

**Consistency check**

To check how significantly consistent the assigned weights are, some further simple computations will be needed. First the scalar (dot) multiplication of each row of the matrix of weighted factors should be calculated. The Division (x) is the ratio of the dot products to the corresponding eigenvectors. The average division;

$$\bar{x} = \frac{\sum_{n=1}^{n=i} x_j}{n} \quad (3)$$

Hence the consistency indexes (CI) were computed from the expression;

$$\text{CI} = \frac{\bar{x}-n}{n-1} \quad (4)$$

The critical value or Random Index (RI) corresponding to the n number of factors was chosen from the table of random indices (Saaty, 1997) reproduced as Table-2 below.

Finally, it should be noted that a perfectly consistent score will give a CI of 0, but when CI ≠ 0, the level of significance will be checked by calculating the consistency ratio (CR).

$$\text{CR} = \frac{CI}{RI} < 0.1 \quad (5)$$

Once the factors satisfy the condition of equation (5) then it is said to be significantly consistent.

The result of this process for the four factors selected are clearly summarised in the Table-3.

**Table-2.** Critical values for the AHP process (Saaty, 1997).

| N | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Critical value | 0 | 0 | 0.58 | 0.9 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 | 1.51 | 1.48 | 1.56 | 1.57 | 1.59 |

**Table-3.** The AHP scores of the four logistics factors.

| Pairwise comparison | Hygiene | Cost | Emissions | Stress | Nth root | Eigenvector | Dot product | Division (x) |
|---|---|---|---|---|---|---|---|---|
| **Hygiene** | 1 | 9 | 3 | 7 | 3.708 | 0.604 | 2.459 | 4.067 |
| **Cost** | 1/9 | 1 | 1/4 | 1 | 0.408 | 0.067 | 0.266 | 4.000 |
| **Emissions** | 1/3 | 4 | 1 | 5 | 1.607 | 0.262 | 1.065 | 4.065 |
| **Stress** | 1/7 | 1 | 1/5 | 1 | 0.411 | 0.067 | 0.272 | 4.063 |

Consistency index = 0.016; Critical Value = 0.9; Consistency ratio = 0.018

Hence, the consistency ratio of the four factors gives strong evidence that the scores are consistent. Hence, from the eigenvectors computed, it is clear that for choosing a transport mode for the distribution of meat from the abattoir, meat safety/hygiene (0.604 more than 50%) must be considered very highly, followed by reduction in harmful emissions (0.262). Cost of transportation and labourers' stress scored equally as least in the considerations.

**Mode efficiency**

The most important factor has been determined but yet the question remains; which mode then will be most sustainable and efficient? The likelihood will be to select the mode that is judged as most hygienic. But the choice of a particular mode will remain very difficult especially in the case of abattoir with different categories of stakeholders and their different ways of understanding. Besides, taking such a decision will remain atomistic and unbalanced as it would just incorporated the health aspect of the objective leaving the environmental, economic, and societal aspects unconsidered, especially in cases where the eigenvectors are close in proportion. To save this conflict of interest, and lack of balance, the AHP allows a pairwise evaluation of the modes with respect to each decision factor. It follows exactly the same steps outlined above and the results are shown in Tables 4 to 7 below.

**Table-4.** The AHP Scores of the four modes with respect to meat safety/hygiene.

| Pairwise comparison | Walk | Motorcycle | Open vans | Cooling van | Nth root | Eigenvector | Dot product | Division (x) |
|---|---|---|---|---|---|---|---|---|
| Walk | 1 | 1/3 | 1/3 | 1/9 | 0.333 | 0.049 | 0.206 | 4.198 |
| Motorcycle | 3 | 1 | 1 | 1/8 | 0.783 | 0.115 | 0.467 | 4.060 |
| Open Vans | 3 | 1 | 1 | 1/8 | 0.783 | 0.115 | 0.467 | 4.060 |
| Cooling Van | 9 | 8 | 8 | 1 | 4.899 | 0.721 | 3.004 | 4.168 |

Consistency Index = 0.041; Critical Value = 0.9; Consistency Ratio = 0.045

**Table-5.** The AHP scores of the four modes with respect to transport cost.

| Pairwise comparison | Walk | Motorcycle | Open vans | Cooling van | Nth root | Eigenvector | Dot product | Division (x) |
|---|---|---|---|---|---|---|---|---|
| Walk | 1 | 4 | 3 | 9 | 3.224 | 0.555 | 2.299 | 4.139 |
| Motorcycle | 1/4 | 1 | 0.5 | 8 | 1.000 | 0.172 | 0.744 | 4.318 |
| Open Vans | 1/3 | 2 | 1 | 5 | 1.351 | 0.233 | 0.960 | 4.125 |
| Cooling Van | 1/9 | 1/4 | 0.2 | 1 | 0.230 | 0.040 | 0.169 | 4.282 |

Consistency Index = 0.072; Critical Value = 0.9; Consistency Ratio = 0.080

**Table-6.** The AHP scores of the four modes with respect to $CO_2$ emissions.

| Pairwise comparison | Walk | Motorcycle | Open vans | Cooling van | Nth root | Eigenvector | Dot product | Division (x) |
|---|---|---|---|---|---|---|---|---|
| Walk | 1 | 7 | 9 | 9 | 4.880 | 0.715 | 2.965 | 4.146 |
| Motorcycle | 1/7 | 1 | 3 | 3 | 1.065 | 0.156 | 0.644 | 4.127 |
| Open Vans | 1/9 | 1/3 | 1 | 1 | 0.439 | 0.064 | 0.260 | 4.045 |
| Cooling Van | 1/9 | 1/3 | 1 | 1 | 0.439 | 0.064 | 0.260 | 4.045 |

Consistency Index = 0.030; Critical Value = 0.9; Consistency Ratio = 0.034

**Table-7.** The AHP scores of the four modes with respect to worker's stress.

| Pairwise comparison | Walk | Motorcycle | Open vans | Cooling van | Nth root | Eigenvector | Dot product | Division (x) |
|---|---|---|---|---|---|---|---|---|
| Walk | 1 | 1/4 | 1/5 | 1/7 | 0.291 | 0.053 | 0.218 | 4.140 |
| Motorcycle | 4 | 1 | 1/2 | 1/4 | 0.841 | 0.153 | 0.624 | 4.086 |
| Open Vans | 5 | 2 | 1 | 1/3 | 1.351 | 0.245 | 0.997 | 4.067 |
| Cooling Van | 7 | 4 | 3 | 1 | 3.027 | 0.549 | 2.265 | 4.122 |

Consistency Index = 0.035; Critical Value = 0.9; Consistency Ratio = 0.038

The CR values show an overwhelming consistency in scoring as they are all far below 0.1. The eigenvectors reveals a high preference for cooling van with respect to hygiene and a medium preference for the same with respect to stress. There is a high preference for Pedestrian carriage of meat with respect to $CO_2$ emissions and a medium preference for the same with respect to cost. These obviously are evident enough, but yet are inconclusive. The question of the recommendable mode remains unclear even at this point but AHP still provides an easy but factual way forward.

**Optimum value for money**

The next step is to generate a matrix of the eigenvectors for the mode-specific criteria considered. This matrix is termed the Optimum Performance Matrix (OPM) and it gives the proportion of mode-specific preferences for each of the sustainability factors. Table-8 is the OPM for the abattoir logistics in question.

**Table-8.** Option performance matrix for meat distribution modes.

| | Meat hygiene | Transport cost | $CO_2$ emissions | Worker's stress |
|---|---|---|---|---|
| Walk | 0.049 | 0.555 | 0.715 | 0.053 |
| Motorcycle | 0.115 | 0.172 | 0.156 | 0.153 |
| Open Vans | 0.115 | 0.233 | 0.064 | 0.245 |
| Cooling Van | 0.721 | 0.040 | 0.064 | 0.549 |

A multiplication of the RVV from the factors scoring (i.e. [0.604, 0.067, 0.262, 0.067]) with the OPM gives the Value for Money Vector (VFM).

VFM = OPM*RVV

This matrix multiplication returns the optimum utility proportion of each mode option under consideration.

Hence, the VFM calculated for this stage of design is (0.128, 0.132, 0.118, and 0.492) as shown in Figure-2 below. This is full of facts and evidence.

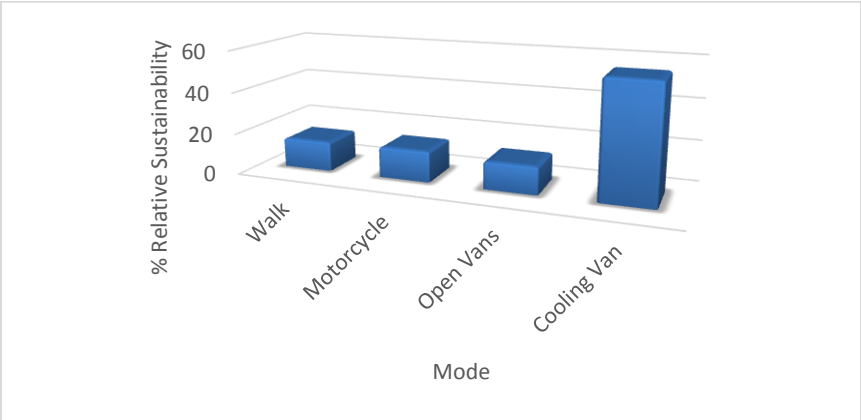


**Figure-2.** Overall relative sustainability of the mode options.

## CONCLUSION AND RECOMMENDATIONS

Based on this AHP demonstration, it is now clear that for a sustainable meat distribution from the abattoir, the Cooling Van option with VFM of 0.492 will be recommended. The fact that the rest of the options did not score up to 20% each as shown in figure 6, they should be highly discouraged. It is about time abattoir operators stopped basing their choices on cost and profitability alone, as that would tantamount to selfishness. The interest and the health of the society that they are serving must be set as a priority because there would be no abattoirs if there were no meat demand and sustainability suggests that the efficiency involved in meeting these demands at present will be a pointer to having the demands in future. As a matter of fact, the cost of improving meat safety as it regards to meat transportation is far less than the social cost of food poisoning from infested meats.

It is therefore, recommended that financial institutions in developing countries should be ready to support sustainable abattoir projects through issuance of loans, grants, and debentures to abattoir managers. The governments, at all levels, should be ready to operate a model abattoir in their jurisdictions either by completely public ownerships or by public and private partnerships; this will stimulate individual abattoir operators to live up to their expectations. Enlightenment and education of the public is very important. Costumers should be well informed about the possible microbial contents of the meat they buy. The habit of meat inspection should not be ignored; more inspectors should be employed, trained and remunerated accordingly in order to ensure compliance to relevant guidelines. In as much as it has been well noted that finance is a major limitation and constraint in most developing countries, it is yet no good enough reason to sacrifice sustainability and jeopardize the future.

## FURTHER STUDIES

In as much as this paper could be considered to be reasonably informative and evidently illustrative, it is yet a qualitative review. Further work is needed to be done with real data of available mode choices, frequencies, and meat safety for specific case studies.

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