Risk analysis of inland waterways transportation on the Niger Delta Basin, Nigeria

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Abstract

This study aimed at analyzing accidents and risk on inland waterways transport operations in the Niger delta basin, Nigeria. Quantitative data obtained from the database of the National Inland waterways Authority (NIWA) were subjected to risk assessment methods. The results reveal an estimated average individual risk (AIR) value of 6.2x10^-5, a fatal accident rate (FAR) of 975 fatalities per 8640 exposed hours; and accident frequency rate (AFR) value of 0.7% for the inland waterways of Niger delta. It concludes that waterways of Niger delta have high risk indices and potentials of accident occurrence due to poor maintenance dredging, enforcement of regulations; and thus recommends that NIWA should invest optimally in safety awareness and policy enforcement for sustainable waterways operations in Nigeria.

Keywords: Accident; Fatality; Inland waterways; Risk; Transport

1. Introduction

The use of waterways is one of transportation alternatives available to most shippers but it is an integral part of the overall transportation system. It is predominantly intermodal transportation because a high percentage of waterway traffic is interchanged with other transportation modes (Adeniran and Shamusideen, 2017). For the shippers who can use the waterway system, it provides a low-cost alternative. Inland waterway transportation ranks at or near the top among other transportation modes in terms of ton-miles produced per unit of energy consumed, and the number of employees and man-hours as well as other resource inputs. It is an important factor in assuring the Nation of a highly competitive and efficient transportation system (Adejare, Nwilo, Olusina and Opaluwa, 2011).

However, the problems associated with inland waterways operations in Nigeria include: Lack of infrastructure including ferry services, mechanised boats and standard jetties; Poor maintenance of the waterways where most are covered with water hyacinth, sand bars and other vegetation; Lack of maintenance dredging and navigational services; Absence of regulations with respect to boat driver/operator education and training on safety practices (Atubi, 2013); and Non existence of a framework for valuation of risks and accidents on the inland waterways of Nigeria, particularly the Niger Delta. In the light of the above, this research aims to evaluate the risk indices associated with travel on the waterways of Niger Delta, Nigeria. This will no doubt raise critical research questions as to what would be the estimated value of average individual risk (AIR), fatal accident rate (FAR) fatalities per number of exposed hours; and accident frequency rate (AFR) on the waterways.

2. The Risk Concept

Kristiansen (2005) asserts that the concept of risk stands central in any discussion of safety. Referring to a given system or activity, the term ‘safety’ he noted is normally used to describe the degree of freedom from danger, and the risk
The concept is a way of evaluating this. The term ‘risk’ is however, not only used in relation to evaluating the degree of safety and the risk concept can be viewed differently depending on the context. Engineers tend to view risk in an objective way in relation to safety, and as such use the concept of risk as an objective safety criterion. Among engineers the following definition of risk is applied:

\[ R = P \cdot C \]

where \( P \) = the probability of occurrence of an undesired event (e.g. a plane crash) and \( C \) = the expected consequence in terms of human, economic and/or environmental loss. Risk is often calculated for all relevant hazards, hazards being the possible events and conditions that may result in severity. For example, a hazard with a high probability of occurrence and a high consequence has a high level of risk, and a high level of risk corresponds to a low-level safety for the system under consideration. The opposite will be the case for a hazard with a low probability and a low consequence. Safety is evaluated by summing up all the relevant risks for a specific system (Kristiansen, 2005).

2.1. Time in Transit Theory

The Time in Transit theory explains the issue of tradeoff between freight- cost-time and timely delivery which could be applicable to building an econometric model (Weng, Ge, and Han, 2016). Using the Japanese Census of Logistics, his paper examines the cost influence of distance and time across shipping modes. It is revealed by earlier researchers that business enterprises are likely to pay more for short-distance shipments by truck, ship and railroad transportation, as shown in figure1 (Appendix 1); implying that the effect of short distances on rates as per-mile freight rates tends to decline with distance as the ratio decreases (Krugman, 1991).

3. Material and methods

The objective to evaluate the average individual risk (AIR) on the waterways was treated with secondary data sourced from NIWA and Marine Police by descriptive statistics considering the relationships:

- **AIR** = \([\text{Fatalities/ year}] \cdot [\text{Journeys/person}] / [\text{Journeys/year}]\)
- **Fatal accident rate, FAR** = \([\text{Fatalities/ year}] \cdot [\text{Exposure time (journey hours/year x journey duration)]} / \text{Exposed hours}\)
- **Accident frequency rate, AFR** = \([\text{DI}] / [\text{EMP. AH}] \times S / 1\) where:
  - DI = number of injuries or work accidents per year
  - EMP = number of operators or users
  - AH = average annual hours work per operator
  - S = Scaling factor derived as worker-hours

3.1. Derivation of Quantities for the variables of AIR, FAR and AFR

The following framework is applied to the determination of the afore stated risk indices on the waterways of Niger delta basin.

- **fatalities**: the total number of deaths arising from boat mishaps on a waterway in the Niger Delta basin in persons.
- **journeys**: the total number of trips per boat multiplied by 2 indicating a to and fro journey.
- **passenger/persons**: the total number of passengers or persons on board a boat multiplied by 2 for a to and fro journey.
- **exposure/journey time**: the total number of times in hours taken for a to and fro trip for all trips multiplied by the number of boats \((\text{hrs x 2 x no. of boats})\).
- **injuries per year**: the total number of injuries arising from boat mishaps on a waterway recorded per annum in persons.
- **operators**: the total number of boat drivers assumed to be one driver plus one attendant for each boat multiplied by the number of boats operating on the waterway \((\text{2 x number of boats})\).
- **average annual work hours per operator**: the total number of to and fro trip hours per month multiplied by 12 divided by total number of operators.
- **scaling factor**: derived as worker-hour equivalent to the total to and fro trip hours per month devided by number of operators.
4. Results

Table 1 shows the risk analysis indices for the selected waterways of the Niger Delta. It further reveals the extent to which a waterway is safe or otherwise and as well reveals the extent to which a user or operator is exposed to risks on the waterways. Hence the analysis reveals an average individual risk (AIR) of $5.3 \times 10^{-5}$, $1.1 \times 10^{-5}$, $3.4 \times 10^{-6}$, $2.0 \times 10^{-5}$, $2.1 \times 10^{-5}$, $5.9 \times 10^{-6}$, $1.8 \times 10^{-5}$, $9.1 \times 10^{-5}$, and $3.5 \times 10^{-4}$ for the selected waterways of Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers state respectively. Hence this gives an aggregate value of $6.2 \times 10^{-5}$for the entire inland waterways of Niger delta.

Table 1 Computation of AIR, FAR and AFR for a period of 1997 to 2021

<table>
<thead>
<tr>
<th>Niger Delta Basin</th>
<th>Fatalities</th>
<th>Journeys</th>
<th>No. of Passenger/ persons</th>
<th>Exposure/ Journey time</th>
<th>Injuries per year</th>
<th>No. of Operators</th>
<th>Average annual work hrs per operator</th>
<th>Scaling factor</th>
<th>AIR</th>
<th>FAR</th>
<th>AFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abia</td>
<td>52</td>
<td>4608</td>
<td>53736</td>
<td>84696</td>
<td>0</td>
<td>384</td>
<td>220.56</td>
<td>18.4</td>
<td>$5.3 \times 10^{-5}$</td>
<td>8.5</td>
<td>0</td>
</tr>
<tr>
<td>Akwa-Ibom</td>
<td>30</td>
<td>5616</td>
<td>230856</td>
<td>66864</td>
<td>0</td>
<td>468</td>
<td>142.87</td>
<td>1.2</td>
<td>$1.1 \times 10^{-5}$</td>
<td>3.9</td>
<td>0</td>
</tr>
<tr>
<td>Bayelsa</td>
<td>03</td>
<td>7680</td>
<td>80064</td>
<td>83976</td>
<td>0</td>
<td>640</td>
<td>131.21</td>
<td>10.9</td>
<td>$3.4 \times 10^{-6}$</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Cross River</td>
<td>44</td>
<td>6216</td>
<td>159000</td>
<td>84744</td>
<td>57</td>
<td>518</td>
<td>163.60</td>
<td>13.6</td>
<td>$2.0 \times 10^{-5}$</td>
<td>7.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Delta</td>
<td>9</td>
<td>6384</td>
<td>73128</td>
<td>37512</td>
<td>8</td>
<td>532</td>
<td>70.51</td>
<td>5.9</td>
<td>$2.1 \times 10^{-5}$</td>
<td>0.7</td>
<td>0.13</td>
</tr>
<tr>
<td>Edo</td>
<td>8</td>
<td>4656</td>
<td>74376</td>
<td>84432</td>
<td>0</td>
<td>388</td>
<td>217.60</td>
<td>18.1</td>
<td>$5.9 \times 10^{-6}$</td>
<td>1.3</td>
<td>0</td>
</tr>
<tr>
<td>Imo</td>
<td>12</td>
<td>1920</td>
<td>20016</td>
<td>65064</td>
<td>6</td>
<td>160</td>
<td>406.65</td>
<td>33.9</td>
<td>$1.8 \times 10^{-5}$</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>Ondo</td>
<td>95</td>
<td>5472</td>
<td>64896</td>
<td>87600</td>
<td>285</td>
<td>456</td>
<td>192.11</td>
<td>16.0</td>
<td>$9.1 \times 10^{-5}$</td>
<td>16.1</td>
<td>5.2</td>
</tr>
<tr>
<td>Rivers</td>
<td>491</td>
<td>6672</td>
<td>109872</td>
<td>84456</td>
<td>346</td>
<td>556</td>
<td>151.90</td>
<td>12.7</td>
<td>$3.5 \times 10^{-4}$</td>
<td>79.9</td>
<td>5.2</td>
</tr>
<tr>
<td>Total</td>
<td>744</td>
<td>49224</td>
<td>865944</td>
<td>679344</td>
<td>702</td>
<td>8204</td>
<td>1696.92</td>
<td>130.7</td>
<td>$6.2 \times 10^{-5}$</td>
<td>975</td>
<td>0.7</td>
</tr>
</tbody>
</table>

The table also shows the fatal accident rate (FAR) of 8.5, 3.9, 0.5, 7.2, 0.7, 1.3, 1.5, 16.1, and 79.9 respectively for the selected waterways. This typifies the rate at which fatal accidents occur on the respective waterways. Table also reveals the accident frequency rate (AFR) for the selected waterways, which is an indication of the extent to which an operator is exposed to injuries when a boat mishap occurs on the waterways. Thus, a value of 0%, 0%, 0%, 0.9%, 0.13%, 0%, 0.31%, 5.2%, and 5.2% was derived for the selected waterways of Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers state respectively. Hence this gives an aggregate value of

5. Discussion

Noteworthy, the research questions dwell on the risk assessment of the selected inland waterways of the Niger delta basin. This research reveals in Table 1 the risk analysis indicators for the selected waterways in the Niger Delta. It further reveals the extent to which a waterway is safe or otherwise, and as well shows the extent to which a user or operator is exposed to risks on the waterways. Hence this analyses an average individual risk (AIR) of $5.3 \times 10^{-5}$, $1.1 \times 10^{-5}$, $3.4 \times 10^{-6}$, $2.0 \times 10^{-5}$, $2.1 \times 10^{-5}$, $5.9 \times 10^{-6}$, $1.8 \times 10^{-5}$, $9.1 \times 10^{-5}$, and $3.5 \times 10^{-4}$ for the selected waterways of Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers state respectively, and thus gives an aggregate value of $6.2 \times 10^{-5}$for the entire inland waterways of Niger delta. This is in agreement with the work of (Sounge In: Kristiansen, 2005) that analysed the safety level of ferries in the UK and revealed an AIR of $6.4 \times 10^{-7}$ [fatalities/person]. Our analysis further confirms that the safety level of ferries in the UK is safe, although higher than for the UK ferry users, when compared to other types of transport (for example Driving $= 1.0 \times 10^{-4}$, Railway$= 2.0 \times 10^{-6}$, and All accidents$= 3.0 \times 10^{-4}$) in the UK. These indices when measured in Nigeria and compared
with the results of this study would apparently be higher due to exposed higher risks on road, rail and air transport in Nigeria.

The table also shows the fatal accident rate (FAR) of 8.5, 3.9, 0.5, 7.2, 0.7, 1.3, 1.5, 16.1, and 79.9 respectively per 518400 exposed minute equivalent to 8640 exposed hours, on the selected waterways. This typifies the rate at which fatal accidents occur on the respective waterways. These values are in tandem with Kristiansen (2005) that revealed a fatal accident rate of 8.8 [fatalities] per 108 exposed hours. Thus, an aggregate of 975 fatalities per 8640 exposed hours is revealed which is far higher than the exposed risk value of 660 per exposed 108 hours on motor bikes ride in the UK. The analysis also reveals the accident frequency rate (AFR) for the selected waterways, which is an indication of the extent to which an operator is exposed to injuries when a boat mishap occurs on the waterways. This is in tandem with some outcomes of Awals, Islam, Hoque, and Hoque (2015).

Thus a value of 0%, 0%, 0%, 0.9%, 0.13%, 0%, 0.31%, 5.2%, and 5.2% was derived for the selected waterways of Abia, Akwa-Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondo, and Rivers state respectively with an aggregate value of 0.7%, for the entire inland waterways of Niger delta. This also is validated by the maritime waterway risk frameworks of Du, Goerlandt, and Kujala (2020) as well as that of Weng, Ge, and Han (2016)

6. Conclusion

This study that analysed accidents and risk on inland waterways transport operations in Niger delta, Nigeria was able to reveal significant risk indices. In order to achieve this aim, at least two waterways were selected from each state of the Niger Delta area, due to their strategic and economic importance. Hence the application of the risk assessment methodology further developed in this study estimated an average individual risk (AIR) value of 6.2x10^{-5}, a fatal accident rate (FAR) of 975 fatalities per 8640 exposed hours; and an accident frequency rate (AFR) value of 0.7% that revealed that it was risky to travel on the waterways of the Niger delta.

Compliance with ethical standards

Disclosure of conflict of interest

The Authors conducted the research together and hence no conflict of interest herein.

References


