Safety Science 79 (2015) 324–335

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/ssci

Risk assessment of petroleum product transportation by road: A framework for regulatory improvement

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ARTICLE INFO

Article history:
Received 20 December 2014
Received in revised form 11 May 2015
Accepted 29 June 2015
Available online 10 July 2015

Keywords:
Accident risk assessment
Truck tanker transportation
Petroleum products
Regulatory enhancement
Nigeria

ABSTRACT

Accidents involving transportation of petroleum products by road has been associated with high frequency of occurrence and high safety consequences in developing countries. Using Nigeria as case example, we analysed 2318 accidents involving truck tankers from 2007 to 2012 with a tailored risk assessment framework. The result shows 79% of the accidents were caused by human factors, mainly dangerous driving. More than 70% of the accident resulted in loss of containment leading to spills, fires and explosions. 81% of the accidents resulted in either injuries, fatalities or both. Most of the 972 accidents with fatalities recorded 1–5 fatalities with occurrence frequency of 0.89. The analysis ranks geographical regions (states) in order of accident consequences and frequencies to enhance regulatory distribution. About 7 million USD was estimated as the average cost per accident. Estimated costs are significant and should motivate improved policy design.

1. Introduction

Transportation of petroleum products by road truck creates numerous opportunities for hazardous materials to be accidentally released into the environment. Depending on the volume upon Loss of Containment (LOC), chemical properties, sensitivity of host environment and proximity of human presence, such releases have safety and environmental consequences. This is especially a problem in developing countries where often towns and villages are situated very close to major roads serving as key transport corridors thereby increasing accident vulnerability (Fabiano et al., 2002; Anifowose et al., 2011). Two different perspectives are often in conflict in the transportation of petroleum products: While operators are particularly interested in profit, the regulatory agencies are interested in ensuring public and environmental safety. Hence, proper accident investigation practices governed by risk assessment principles among operators and regulators are required in order to understand and prevent severe hazards posed by the dangerous properties of petroleum products transported by road (Lawler, 2005).

Risk assessment of transportation of hazardous materials (such as petroleum products) has attracted research attention during the last 20 years (Yang et al., 2010) especially in the context of safe transportation using pipelines (Dziubiński et al., 2006; Citro and Gagliardi, 2012), railway (Liu et al., 2013; Saat et al., 2014) and road (Verter and Kara, 2001; Fabiano et al., 2002, 2005; Gheorghe, 2006; Lieggio Junior, 2008; Bubbico et al., 2009; Centrone, 2009; Guo and Verma, 2010; Tomasoni et al., 2010; Yang et al., 2010). Within the research conducted on transportation of hazmat on roads three approaches can be distinguished. The first approach is the development of frameworks for improving emergency responses based on road, weather, and traffic factors (Fabiano et al., 2005). The second is based on conducting survey and accident risk analysis from historic data to divulge accident characteristics such as frequency of occurrence, accident consequences, and identification of causal factors (Fabiano et al., 2002; Yang et al., 2010; Shen et al., 2013). The last approach focuses on the development of decision making frameworks aimed at improving choice of truck capacity (Guo and Verma, 2010) and route selection (Verter and Kara, 2001; Fabiano et al., 2002; Volkovas et al., 2005; Lieggio Junior, 2008). However, little attention has been given to developing risk assessment model for decision

Abbreviations: AGO, Automated Gas Oil; DPR, Department of Petroleum Resources; FRSC, Federal Road Safety Commission; HHK, House Hold Kerosene; LOC, Loss of Containment; NEMA, National Emergency Management Agency; NNPC, Nigerian National Petroleum Corporation; NOSDRA, National Oil Spill Detection and Response Agency; PMS, Premium Motor Spirit; PPPRA, Petroleum Products Pricing Regulatory Agency; USDOT, United States Department of Transport.

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http://dx.doi.org/10.1016/j.ssci.2015.06.022
0925-7535/

making in developing countries where the effectiveness of regulation for accident prevention and emergency preparedness and response is often constrained by limited regulatory resources (Aprioku, 2003).

Moreover, there is a need to have a risk assessment framework that exposes the financial implications of accidents involving petroleum product tankers. This is because due to the small and often fragmented character of petroleum product transport operators in developing countries, regulatory enforcement is often lacking and these companies cling to the perception that adhering to good safety and environmental standards is expensive. Hence, there is a need to uncover the real, and often high, but hidden costs of poor safety standards to operators via risk assessments.

Using the case example of Nigeria, we present a regulatory improvement framework based on the identification of relative accident risk hotspots across states and evaluation of financial consequences of accidents involving petroleum product truck transport using fragmented spatiotemporal data. The framework will provide regulators with the means to effectively prioritize resources when regulating transportation of petroleum products. Similarly, by adding a financial dimension to the risk analysis, regulators can use the framework to prompt strong regulatory incentive for improving hazmat transport.

2. Case example: petroleum product distribution in Nigeria

The downstream subsector of petroleum industry in Nigeria is characterised by a complex assortment of infrastructure and processes including refining, distribution, transportation and retailing of petroleum products. The industry supplies about 40 million litres of petroleum products per day to an estimated 170 million people across 36 states and Abuja (NNPC, 2012) mainly via trucking operations (see Fig. 1). In addition to the government owned retailing company (Nigerian National Petroleum Corporation-Retail), there are 6 Major Marketers and over 10,200 Independent Marketers all involved in transportation and distribution of petroleum products (PPPRA, 2006). In 2012 the Federal Road Safety Commission (FRSC) reported the involvement of over 5000 petroleum product tankers in daily haulage on Nigerian roads, accounting for approximately 95% of the country's petroleum product transport volume moving on the road system.

This transport system has been largely responsible for accidents and disasters that pose risks to human safety and the environment (Dare et al., 2009; BBC, 2012). However, regulatory activities (including accident prevention, preparedness and response) have mainly been constrained due to inadequate funding. For instance, while the FRSC have safety requirements and guidelines for articulated lorry (tankers/trailers) operations in Nigeria that covers registration, licencing and emergency preparedness their operations are not efficient (Oluwadiya et al., 2009; Ambituuni et al., 2014). This calls for enhanced identification of accident hotspots for effective regulatory resource prioritisation and distribution as a risk management strategy. A risk assessment model is therefore required in light of the limited access to good quality data which has often contributed to research limitation in Nigeria (Anifowose et al., 2012; Omodanisi et al., 2014).

The highly articulated, small but politically sensitive nature of truck tanker operators in Nigeria (Majekodunmi, 2013), also typifies a case where a framework is required for integrating accident cost analysis so that regulators can build up a case to enforce good safety and environmental standards and also manage the risk perception of operators.

3. Method

3.1. Data

Data collection was a noticeable challenge for this article as it is for many studies in developing countries. As there is no public data base in Nigeria, 2318 accident reports were obtained from 4

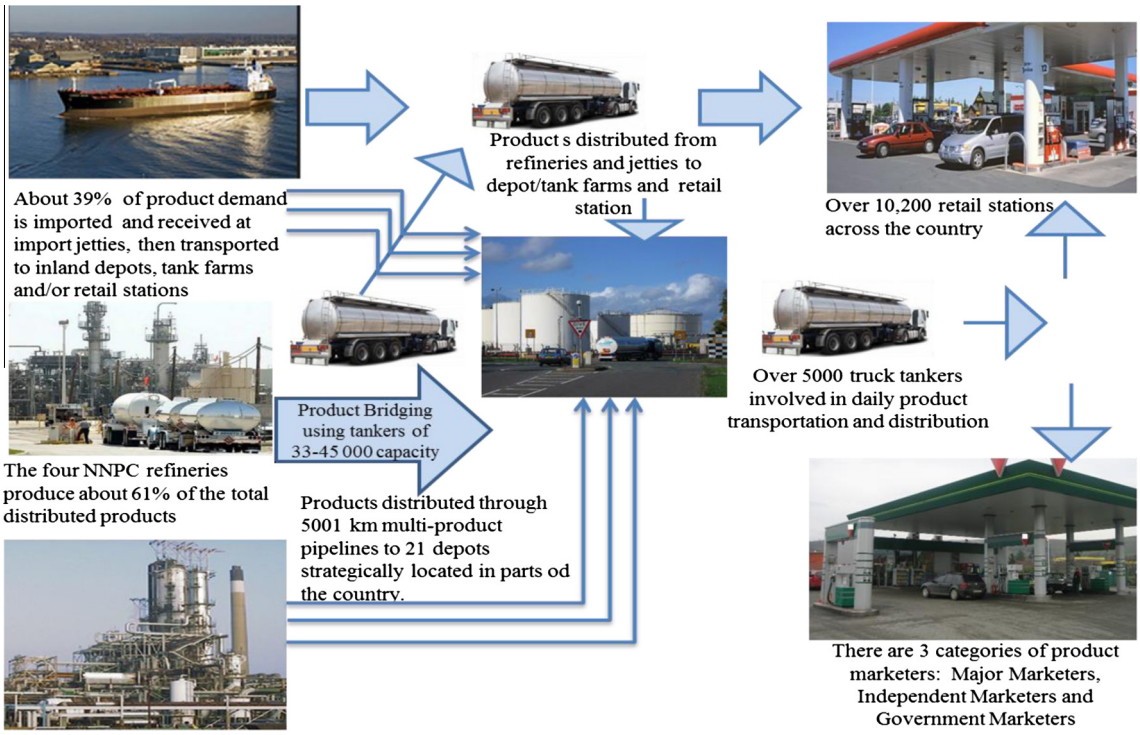

Fig. 1. Downstream structure of Nigerian petroleum industry (Note: pictures used in this diagram were obtained from public domain and used for illustrative purposes only. They do not represent any company's facility).