Climate Change and Urban Road Transport

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***Abstract*— identify the areas within the municipality which are most vulnerable to sea level rise and to develop adaptive responses and interventions in order to maintain road functionality. Parameters modeled were traffic volume changes, travel time and volume to capacity ratio – for the main roads in the areas identified. How vulnerability and the development of adaptive strategies to sea level rise could be addressed by municipalities.**

***Index Terms*—climate, road transport, vulnerability, Emme/2 model**

I. INTRODUCTION

A. Information

Infrastructure like bridges, roads and railway lines, can be affected by sea level rise, flooding and increased storm events, and adaptation plans should be developed to cater for these events. However, most of the research and regulatory efforts on the issue of transportation and climate change are directed towards quantifying, reducing and limiting carbon emissions. This resulted in many countries producing guidelines, inventories and even laws and bills in order to measure and target carbon emissions from all sectors, including transportation. These areas are linked through a network of roads. Predicted consequences are summarized as follows:

- Increases in the maximum and minimum temperatures are predicted, with an increase in the number of hot days experiencing temperatures exceeding.
- Rainfall will increase slightly. However, the distribution of this rainfall will change, with longer periods of no rainfall and shorter periods of intense rainfall.
- The sea level rise and increased extreme weather events will result in damage of infrastructure and coastal vegetation. Increased flooding is also predicted. Flooding will result in an increase in the high-level tide and coastal erosion.
- Water availability in the local catchment is predicted to decrease, thus resulting in less water being available for human and industrial consumption.
- Loss of biodiversity due to temperature and precipitation changes.

II. DEFINING ROAD VULNERABILITY

A definition proposed by Bredica (2002) is: "Vulnerability in the road transportation system is a susceptibility to incidents that can result in considerable reductions in road network serviceability. These incidents may be more or less predictable, caused voluntarily or involuntarily, by man or nature". The same author states that "road vulnerability analysis regards the network as a whole and involves identifying a spectrum of incidents, collecting data on probabilities and consequences to estimate risk, performing various studies and experiments to set values for desirable/acceptable serviceability, as well as investigating and assessing the effects of possible mitigation measures and improvement strategies". A review of the studies on this topic shows that vulnerability assessments in road transport networks have been performed at national, regional and international level.

III. METHODOLOGY

Defining the boundaries of the study and collection of data, development of the multi-criteria and vulnerability assessment models and the application models, followed by an analysis of the limitations and uncertainties. Through the multicriteria assessment three geographical areas were identified. Roads in these areas would have the potential to be affected by sea level rise. The road transport network within these three areas was subsequently investigated by using transportation network model. Worst case scenarios, in which affected major roads were considered unusable, were modeled and the consequences of changed traffic patterns were measured using specific traffic criteria, i.e. volume, travel time and volume to capacity ratio.

IV. STUDY BOUNDARIES AND DATA COLLECTION

The study the boundaries were defined, and the components of the transportation system and the choices around natural hazards were narrowed down. With regard to infrastructure, it was decided that the study would focus on roads only. With regard to vehicle type, **all vehicles** that made use of the road network were considered. Both public and private transportation were considered. **Operations** were the focus of the modeling and vulnerability assessment. A significant proportion of the analysis and discussion is based on operational performance of the road network. Performance measures mentioned by the National Department of Transport are mobility, accessibility, livability and sustainability. Mobility measures were linked to three performance characteristics (volume, travel time and volume to capacity ratio) used. This is also supported by the literature on road vulnerability analyses, as these performance characteristics are used in reliability studies and accepted as measurements for the performance of road networks. This study focused on sea level rise and associated flooding. Such flooding was included in the analysis of one of the case studies (the Umgeni River mouth area), as in this specific case it proved to be very relevant.

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Step 1. Engage affected parties.
Engage and retain decision-makers and those affected by future climate change.
Step 2. Assess current vulnerability.
Use experience to assess impact and potential damage. Understanding adaptive capacity, critical threshold and coping ranges is helpful.
Step 3. Estimate future conditions.
Use climate environmental and socio-economic scenarios to determine future policy and development.
Step 4. Estimate future vulnerability and identify adaptation strategies.
Use the two previous steps (current vulnerability and future conditions) to identify future vulnerability and adaptation strategies.
Step 5. Decision and implementation.
Incorporate results into risk management strategies and follow through with these.

Table 1 Vulnerability assessment process

Characteristics	Isipingo Area	Bayhead Area	Umgeni River Mouth
Land use	Industrial and residential. The Southern Durban Basin to which the area belongs is one of the most important industrial hubs in the region	Industrial (linked to the harbour)	Residential, commercial and recreational (including a mangrove nature reserve)
Extent of area below 2 m predicted to be affected by sea level rise	About 5 km^2	About 4 km^2	Large areas of land, reaching up to 10 km inland along the Umgeni River and spanning 8 km along the coast
Number of major roads situated below the 2 m contour line	Two, i.e. Prospecton Road and Joyner Road	One, i.e. Bayhead Road	Several bridges intersected the 2 m contours, closest to the sea being the M4 bridge and the Masabalala Yengwa Avenue bridge
Number of major roads situated below the 4 m contour line	One, i.e. N2 Highway	Two, i.e. Bluff Road Iran Road	Same as above
Essential services in proximity to the area	1 school 1 major hospital 1 fixed clinic 2 police stations 1 fire station railway lines gas lines	3 schools 1 police station substantial lengths of railway important for the harbour activities	4 schools 1 clinic

Table 2. Areas identified to be vulnerable to sea level rise

V. VULNERABILITY ASSESSMENT

In the first stage, decision-makers and stakeholders were engaged in a scoping exercise, in order to gauge an initial assessment of the vulnerability of each area. This was done in a limited way and only a few key players at municipal level (from the departments of transport, environment and coastal management), academics and scientists were consulted through a series of open-ended, partially structured discussions. A wider consultation process was beyond the scope of this study. In the second stage, current traffic conditions were assessed. model was used to calculate present traffic volumes, travel times and volume to capacity ratios (V/C), based on existing transportation input data. This was done for each of the three areas identified as vulnerable. In the third stage, future conditions were estimated. This step involved establishing projected scenarios of future environmental, social and economic conditions that were likely to affect the transportation system. Projections were made by experts in four institutions. In the fourth stage, future road vulnerability was estimated and adaptive strategies were proposed (see "Results and Discussions" further on). Practically, this was done by using the Emme/2 model to calculate traffic changes for the three road networks in the areas predicted to be flooded and by investigating different adaptive measures in order to maintain the current functionality of the surrounding transportation network. Stage five, in which decisions should be taken and measures implemented in order to decrease road vulnerability by applying the adaptive strategies proposed, was beyond the scope of this study. Therefore, although some of the steps (i.e. steps 1 and 5) were performed partially or not at all, the vulnerability assessment framework from the literature was nevertheless followed.

VI. CONCLUSIONS

The purpose of this investigation was to identify areas within the Municipality that are most vulnerable to the impacts of sea level rise and to assess the impacts of projected changes on the surrounding transportation network. This study also intended to present a model of vulnerability analysis and the development of adaptive strategies for municipalities. These are needed for transportation network planning. Identification of the most vulnerable areas was done by applying a simplified.

In this way, the vulnerability of transportation infrastructure to projected sea level rise (via inundation of road links) was assessed. Performance indicators were used during the vulnerability assessment phase to measure the efficiency of the road network before and after inundation. The 'before' and 'after' scenarios formed the basis of vulnerability comparison.

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