Determination of logistic deterioration models and rehabilitation strategy for urban water pipe distribution system in the developing world

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BACKGROUND

Water distribution networks/ systems (WDSs) - major component of a water utility's asset. Account up to 80% of the total expenditure. WDSs face a challenge of deterioration, caused by a combination of physical, environmental, and operational factors. Deterioration causes pipe failure in form of breaks, leakages, bursts etc. Pipe failure increases non-revenue water (NRW). This increases the cost of operation of the system. NRW is at 30.73% and 33% in large and small towns respectively in Uganda yet WHO threshold for NRW developing economies is 25%. A need for proactive approaches for management to ensure the systems operate satisfactorily, function efficiently, and continuously at low costs is highly recommended. To deal with these challenges, models are required.

OBJECTIVES

- Identify the most significant factors associated with pipe failures
- Predict pipe failure occurrences all of which can inform prioritization of rehabilitation schemes amidst limited budgets.

METHODS

- Historical pipe information of 1964 to 2017 was obtained from the National Water and Sewerage Corporation (NWSC) database. 55 pipelines with a nominal diameter of 150 – 300 mm and 84 pipe sections were selected.
- Pipe attributes (Physical, environmental, and operational) were collected; pipe material, installation year, number of failures, replacement costs, pipe location, soil type, distance from the road, depth, traffic impact, population density, number of customers, pressure rating, average system pressure, size of pipe, length, and its location.
- The pipe attributes were grouped into categorical (qualitative) and non-categorical (quantitative) variables.
- Anova was used to compare the significance for each of the qualitative variables to pipe failure by determining the difference between means.
- The relationship between the quantitative variables and pipe failure was measured using spearman's correlation coefficient (ρ). The level of significance was defined at 0.05.
- The useful life period, defined by a constant failure rate was determined and different ranges of break rates were developed based on the condition rating scale for water mains developed by (Al-Barqawi and Zayed, 2006). The condition of no failure was considered the reference variable in the binary and multinomial logistic regression methods to develop the models.

Frequency of breaks	Linguistic scale	Criteria	Dependent variable (Y)
0.0 - 0.2	Very Good	Newly/recently installed or like new with no signs of breaks or deterioration.	0
0.2 - 0.5	Good	Pipe still intact. Probability of pipe breaks less 50%.	0
0.5 - 1.0	Moderate	Some signs of pipe breaks noted. Probability of pipe breaks 50 to 75%.	1
1.0 – 2.0	Poor	Significant signs of pipe break. Probability of pipe breaks 75% or more.	1
≥ 2.0	Critical	Numerous pipe breaks. Probability of pipe breaks more than 90% .	1

RESULTS

- Pipe failure had a high negative correlation with pipe age and pipe depth. Implying pipe failure was more likely to happen during the initial installation age which decreased over time; pipes buried deeper were less likely to fail than pipes buried closer to the soil surface.
- The correlation between pipe failure and average pressure, distance from the road and pipe size was positive, implying that pipe failure increased with increasing pressure, pipe size and distance from the road.

CONCLUSION

- Traffic could not be used in prediction of pipe failure because whether the traffic is low, medium or high, the pipes would still fail, however the failure rate is higher at junctions and intersections.
- Pipe age is the most significant factor in the deterioration of water distribution pipes.
- Binary logistic regression deterioration model had a higher overall prediction efficiency (86%) that its counterpart with a percentage of 75%. From the rehabilitation strategy, it concluded that the pipe section Albert Kook-Muteesa 1 road junction to Lungunja had the highest risk of failure and therefore should be considered first during maintenance or rehabilitation.

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