Regional Road Life Model of Albany Highway – An 80 Year Case Study

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Abstract

Roads are designed to endure physical deterioration over time but the cross-section and alignment is frozen in situ at the time of construction, inevitably leading to premature obsolescence. Recent research has now revealed that in many cases structurally sound roads make way for safer and more efficient road alignments. The Albany Highway, Western Australia's oldest arterial two-lane highway has existed since the 1860's and was constructed using modern techniques during the 1930's. The object of this project is to investigate why roads fail and to develop a new approach for the design life of roads as a function of functional longevity. An assembly of resources encompassing archives, annual reports, maps, manifests, journal articles ,interviews, texts, reconstruction, road inventory and traffic databases were used to develop a research database. Candidate measures relating to road age, location, seal width, traffic and alignments were used in the development of a logistic regression model. The model developed using SPSS software enabled the determination of the relationship between the road characteristics and failure conditions. The findings in the model suggest that curved roads designed with a high geometric standard should incorporate a maximum design life, while curved roads with low geometric standards should be designed in anticipation of early disposal.

1. Introduction

The life cycle of a new section of road on a regional two-lane highway is a staged process that begins at construction and ends at replacement. Prior to construction, the design process employs two main elements, pavement and geometry design. Pavement design incorporates scientific techniques which are utilized to ensure the pavement sustains the expected heavy traffic over the stipulated design life. Main Roads WA currently prescribes a design life of 40 years for new pavements (Main Roads WA TRIM 2010). Road geometry, including the horizontal and vertical alignments, is designed to meet the existing standards for safety and efficiency. Initial construction of a road pavement is followed by a primerseal which lasts for two years before receiving an initial seal. Reseal occurs after 15-20 years and typically includes widening. Signs of structural weakness lead to rehabilitation, which subsequently extends the capacity of the road to withstand more traffic. The pavement is reconstructed at the end of its "operating life".

Martin et al define the "operational life" as the lower bound of the "service" and "requisite/functional" lives of a road pavement (Martin et al. 2006). The "service life" of a road is defined as the time after construction or rehabilitation/replacement in which the pavement reaches a threshold value of the maximum level of pavement distress (a physical condition). "Requisite or functional life" is defined the time after construction or rehabilitation/replacement in which the existing geometry and alignment support the traffic prior to the "road configuration threshold".

The current state of the art paints a vivid picture vis-à-vis "service life". In contrast to this, "functional life" remains a nebulous matter. Currently, pavement design life is approached from the mono-causal perspective that "service life," alone, should determine the design period, but recent studies and existing knowledge within Main Roads WA suggest inclusion of functionality in pavement design life may prove efficacious. Martin et al investigated "Why Pavements are Replaced" and revealed the primary cause for road replacements (Martin et al 2007), was road realignment. This is in contradiction to the generally held belief that structural failure is the usual antecedent to replacement.

"Regional Road Life Model of Albany Highway – An 80 Year Case Study" constitutes a research exploration into the multifaceted history of the prominent highway linking the historical sea port of Albany with Perth, the State Capital of Western Australia. The Perth to Albany Road (as it was originally known) meanders, rises and dives through rolling terrain, crosses ravines and river beds through the lush forests and grassland along its, all told, 404 km of undivided highway. The Albany Highway was still being used by animal drawn transportation at least until 1935 on 16 ft (5 m) wide hodgepodge surface of bitumen and dirt. Today an over 2000 vehicles per day traverse its 24 ft (8 m) wide seal, overtaking lanes, and modern bridges.

Figure 1 Perth to Albany Road 1927: Horse and steam tree-puller in preparation of the two-lane undivided highway (Main Roads WA 1927)

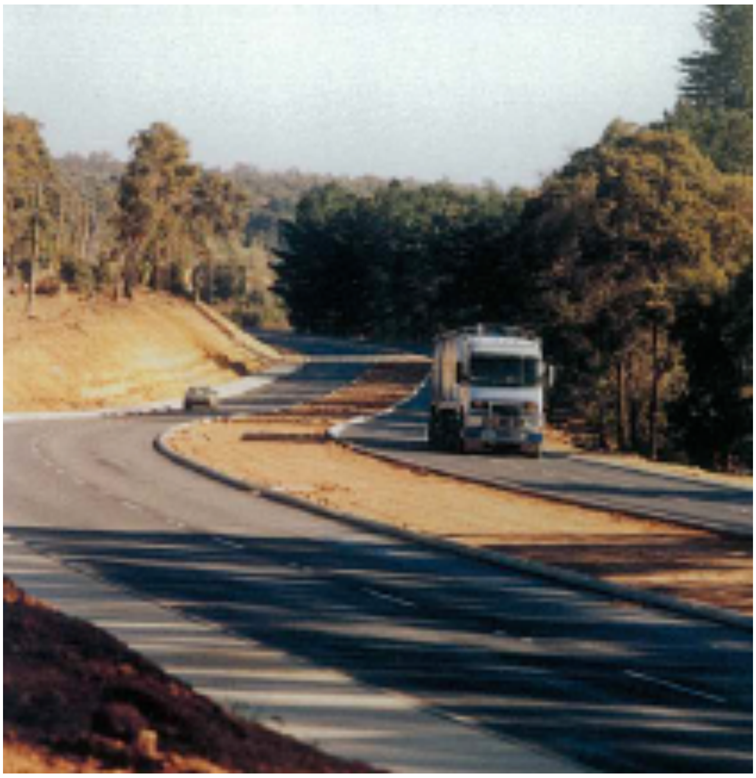

Figure 2 The Albany Highway 1999: Reconstruction of section involved the improvement of 23 curves and construction of a four-lane divided carriageway on Bedfordale Hill (Main Roads WA 1999).

Roadwork and traffic data dating back to 1926 were collated and coalesced into a confluence of databases used for logistic regression analysis in an effort to determine the statistical relationship between the "functional", "service" and "operating" lives of roads. Development of calibrated statistical models designed to forecast the "operating life" of a road section will allow road designers to tailor pavement design life to optimize the utility of future road assets. In addition, Main Roads WA will be better positioned to account for existing road assets.

2. Process

A diverse range of sources were needed in order to review the history of Albany Highway. Notes taken from Main Roads WA Annual Reports, local and state newspapers, journal articles, previous investigations, letters, books, photographs and maps provide a chronological report.

The Case Study's investigation of pavement operating lives can only be achieved in a meaningful way through the employment of quantitative measurements. Achievement of this objective was contingent on the adequate procurement of precise construction records, traffic and inventory data. The inherent unpredictability of content within the archives coupled with the superficial level of detail from the remaining sources left little room for optimism. The following sources have been used

- State Records Office and MRWA Archives (Road works and traffic reports)
- MRWA Annual Reports - 1927-2009 (Road works summaries).
- MRWA Records Department manifests. (Reconstruction works 1926-1945)
- MRWA Pavement Details (Pavement Ages)

- MRWA SLK book (overtaking lanes, river, bridge and other landmark locations)
- MRWA Geometry/Alignment Details (curve intensity)

An Excel Spreadsheet was laid out with columns labelled from left to right denoting location, date, description of intervention, quote, additional details, reference source and map. Each row in the Excel spreadsheet contains information relating to an intervention of some kind and are colour coded according to the information source.

Traffic data was input into a separate Excel spreadsheet. Annual Average Daily Traffic (AADT) and heavy vehicle traffic (HVT) over the highways entire length were available for the years 1976, 1983 and 2005. Prior to 1976, (for example in 1939 and 1950) some traffic volume and composition data was available. Therefore a significant amount of data needed to be estimated. Between 1976 and 2005 traffic data was estimated through interpolation, by calculating the one-year geometric growth rate and applying to the gap period. Data going back to 1935 allowed determination of the growth rate over the 41 year period for several sections. The growth rate was averaged and applied over the full length of Albany Highway.

The reconstruction data was reorganized into a second database which allowed determination of interventions for particular sections along Albany Highway over the full 84 year period. For example a particular 5 km section may have experienced construction in 1935, followed by reconstruction in 1965 and 1995. This allowed pavement lives and the interventions such as seal widening and construction of overtaking lanes to be determined. It also allowed sorting of useful and irrelevant data. Data was considered irrelevant if one or more of the following categories could not be established: age, location, and cause.

A final database was established containing useful replacement data from the second data base and introducing some new candidate measures such as traffic volumes and “curve concentration.” Recent research indicated that a strong relationship exists between geometric consistency of two-lane rural undivided highways and safety (Anderson et al 2009). The lack of technical data available on the Albany Highway precluded the testing of measures related to curve and radius lengths. In response, an improvised measure was developed and coined, the “curve concentration” (curves per km), and input into the database.

The independent variables were age, old seal width, intermediary seal width, new seal widths, speed deficiency, curve concentration (still to be tested), AADT and HVT multipliers. The dependent variable was defined as the cause of road replacement. The dependent variable was split into three distinct categories of functional failure, physical failure and a hybrid between the two. SPSS software package was utilized to perform logistic regression analysis on the data.

3. Results and Discussion

A total of ninety-eight road replacements were analysed in the SPSS model. In thirty-three of road replacements, the cause was due to physical failure.

Observed failure	**Average life**
Physical	33.8
Functional	24
Both	37.9

Table 1 Represents average life for three failure conditions.

Classification

Observed	Predicted			
	physical failure	realignment with remaining life	realignment and physical failure	Percent Correct
physical failure	26	0	6	81.3%
realignment with remaining life	5	19	3	70.4%
realignment and physical failure	4	4	23	74.2%
Overall Percentage	38.9%	25.6%	35.6%	75.6%

Table 2: Represents the logistic regression model's current capacity to predict the causes of road replacements.

Thirty-one replacements were due to functional failure and the remaining thirty-three were because of a hybrid of functional and physical failure.

It is expected that average hybrid life would be equal to physical life, but the results suggest otherwise. The disparity may be due to the high representation of physical failure replacement in the 1960's when maintenance methods were not as effective as in later decades.

This effected a downward bias on the average physical life. For all intents and purposes hybrid life is physical life on a section which has functionally failed at an earlier time. Taking this into account physical life expectancy is 35.9 years. The data suggests functional failure takes place on average 24 years into pavement life, which is significantly less than the physical life of a road.

Pearson-chi squared testing was conducted and found a significant correlation between physical failure and the AADT and HVT multipliers but not with age. This reconciles with theory that the physical life is a function of the traffic and in particular heavy vehicle traffic. The variables of age and AADT multiplier were more significant in predicting functional failure. These results conform to the expected outcomes. The curve concentration variable has not yet been tested and is expected to be an influential variable. At present the model adequately predicts 75.6% of cases.

4. Conclusions and Future Work

Logistic regression modelling is currently in the development stage and drawing conclusions at this point would be premature. The final step involves integrating the candidate measure of curve concentration with the model. It is expected that a model will be developed which can accurately predict the failure condition based on AADT, HVT, pavement age and a measure of the section curve concentration.

Further studies into the relationship between functional, service and operating lives and measures such as curve radius, grade and operating speeds are recommended to build on the findings of this investigation.

5. Acknowledgements

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