Available online at http://www.journalijdr.com

IJDR

ISSN: 2230-9926

International Journal of Development Research
Vol. 09, Issue, 10, pp. 30226-30231, October, 2019

RESEARCH ARTICLE **OPEN ACCESS**

SERVICE LIFE ESTIMATION OF PAINT-RENDERED FACADE IN PUBLIC RESIDENTIAL BUILDINGS IN FOREST CLIMATIC DESIGN ZONE OF NIGERIA

[1,*]Aluko Olaniyi Olanipekun, [2]Adeyanju, Ademola and [3]Bankole Idowu Emmanuel

[1]Department of Architecture, Federal University of Technology, Akure, Nigeria
[2]Department of Architectural Technology, Rufus Giwa Polytechnic, Owo, Nigeria
[3]Department of Architecture, Federal University of Technology, Akure, Nigeria

ARTICLE INFO

Article History:

Received 10th July, 2019
Received in revised form
14th August, 2019
Accepted 02nd September, 2019
Published online 16th October, 2019

Key Words:

Degradation,
Service life,
External paint,
Forest zone,
Maintenance.

***Corresponding author:**
Aluko Olaniyi Olanipekun

ABSTRACT

The financial resources available for infrastructure maintenance and rehabilitation are always limited thus creating a need for efficient resource management and for the ability to predict maintenance actions throughout the infrastructure service period. Service life prediction has assumed a primary role as it allows a more rational use of construction elements and serving as a useful tool in the definition of preventive maintenance plans providing an increase in performance of various building element especially those used in the facades. This research is based on a field data collected through the administration of questionnaires about the state of deterioration of in-service buildings. The degradation is defined by a number of factors that together contribute to the deterioration of painted surfaces thus ending their service life. Out of the 1034 number of buildings that used paint coatings in the facades, a total of 118 buildings was used. In the study, a mathematical model was defined using a linear regression analysis and this enables the coating's deterioration over time to be expressed as a function of various degradation factors. The model which enabled degradation patterns to be identified yielded a minimum (reference) service life of paint coatings of 3 years and maximum reference life of 5 years and an average service life of 5 years. An analysis was then performed that suggested maintenance strategies at interval of 5 years and terminates at a period of 20 years. This study contributes to the maintenance of painted facades through the provision of a lifespan of paint that can be used to generate a maintenance guide which ultimately leads to economic and performance gains.

Citation: ***Aluko Olaniyi Olanipekun, Adeyanju, Ademola and Bankole Idowu Emmanuel*, 2019.** "Service Life Estimation of Paint-Rendered Facade in Public Residential Buildings in Forest Climatic Design Zone of Nigeria", *International Journal of Development Research*, 09, (10), 30226-30231.

INTRODUCTION

The service life prediction of the materials and components of the built heritage is important in achieving longevity, investment benefits and appropriate selection, use and maintenance (Masters, Brandt 1987; Anoop *et al*. 2012). A study performed by Long*et al.* (2001) shows that the building stock represents more than 50% of the national wealth of the developed countries. Consequently, Silva *et al*. (2012) asserted that in order to maintain the value of these assets, both in technical and economic terms, it is paramount that the degradation of constructed assets and their elements are assessed. This is the only way to ensure that the maintenance work over the life cycle is planned as a function of the real degradation mechanisms of the construction materials and components, bearing in mind the degradation factors and the corresponding expected service lives (Chai 2011). Hovde, (2004) and; ISO (15686–1:2000) argue that the service life of a construction element is directly related to the environmental conditions it is subjected to, the quality of the materials used, the workmanship, the service conditions and the maintenance planning. An efficient evaluation of the service life must bear in mind these factors and enable the optimisation of inspection and maintenance plans and the implementation of a more rational management of the resources spent on constructions during their service life (Mejri, Cazaguel and Cognard, 2010). Nowadays, studies are very important to obtain reliability data and to turn these data into useful information for decision-making (Meeker, Escobar 1998). Paint application on building surfaces is the most popular aesthetic expression in Nigeria as expressed by Fawehimi and Adeosun (2001). It was buttressed that paints are manufactured in shade of colours, quality, make and are used in the surface treatment of both interiors and exterior walls of residential and public buildings. Onibokun and Agbola (1991) reports that about 60% of the total cost of the housing expenditure goes into building materials, in which the surface treatment of a building is represented by approximately 5% of the initial cost of construction. This study therefore focuses on the prediction of life span of painted coatings in the forest climatic zone of Nigeria.

Literature review

The façade is a key element of a building and it influences its comfort, safety and aesthetics. The overall performance of the façade depends on the performances of its components: separation, support and facilities (Hermans, 1995). The poor design of construction details, a bad choice of the façade materials (e.g. plaster with high porosity in a marine environment), its inadequate application, and non-existent maintenance are the current problems in buildings' façades. During their service lives, buildings deteriorate and become obsolete. As soon as they are built, the process of decay begins, as well as the deterioration of the fabric and services (Rikey and Cotgrave, 2005). The inevitable process of decay can be controlled and the physical life of the buildings extended if they are properly maintained (Chew, Tan, and Kang, 2004). Maintenance strategies are essential to control the first stages of degradation and prevent the failure of building elements. The selection of the most cost-effective and appropriate strategies can enable better budget allocation and can also minimize the decline in the performance of buildings during their whole life cycle. The design, methods of construction, materials, colour, texture, detailing and finish categorically determine the behaviour of building skin (Aosmohor, 2010). The decision on specification of a particular material goes a long way to determining the future cost of maintenance, quality, life-span and value of the building (Yiu, 2008). Service life of buildings and components is an important issue in evaluation of sustainability, and there is a need for service life planning. Such a planning process aims to ensure that the actual service life is equal to or greater than the design life, while the total economy is taken into account (Christian, Svein, and Per, 2011). The development of service life product standards and standardization of service life design and planning of buildings and constructed facilities are key elements for achieving "Sustainable Construction".

Considerable work has been carried out in the area of service life prediction as requisite tools for helping assess long-term environmental effects, for maintenance management of infrastructure systems, such as roads, bridges, waterways, water distribution and waste-water removal systems, or indeed for maintenance of building envelope systems, envelope components and related materials (Lacasse and Sjöström, 2004). Several service life prediction methods have been put forward in recent years. Conspicuous among them are the empirical methods that try to define the degradation condition of coatings over time in real service conditions by resorting to field work (Shohet, Rosenfeld, Puterman, and Gilboa, 1999; Shohet and Paciuk, 2004). Regardless of the sample's size, after the field work is completed, a graphical and statistical analysis is performed to define degradation paths which relate the loss of performance of the elements to their age (Flourentzou, Brandt, Wetzel 1999; Shohet, Putterman, Gilboa, 2002). The service life prediction model proposed by Gaspar, de Brito (2008) and Gaspar (2009) contains a quantitative index that depicts the global performance of any construction element. This degradation severity index is obtained as the ratio between the extent of the façade degradation, weighted as a function of the degradation level and the severity of the anomalies, and a reference area, equivalent to the maximum theoretical extent of the degradation for the façade. Because of the high costs associated with exploiting and maintaining buildings in addition to the growing awareness of various construction actors of the buildings' limited durability, various studies with the aim of evaluating the degradation and lifecycle of constructions have been made (Chai1; de Brito; Gaspar; and A. Silva, 2014). There are presently various methods and approaches towards service-life prediction. According to Lacasse and Sjöström (2004), the main proposed methods may be classed as deterministic, stochastic, and engineering models. Stochastic models rely on the premise that deterioration is a process explained by random variables which define probabilistic parameters that the average degradation curve does not (Moser 2003), in such a way that knowing the deterioration in a specific instant does not determine its immediate evolution. These models require an extensive data-collection to allow samples to be sufficiently representative, which is not always possible due to time and cost limitations. Deterministic models consist algorithms that model degradation over time, depending on one or more characteristics of the element under analysis, usually yielding an absolute value of its estimated service-life. These models are generally quick and easy to apply even though they are sometimes classified as excessively simplistic, bearing in mind the complexity inherent to the degradation processes of the construction materials and components. The engineering models are an intermediate concept between deterministic and probabilistic models. Based on simpler methods (e.g., deterministic by nature) they allow integrating part of the variability associated with the real world without becoming excessively complex.

MATERIALS AND METHODS

This research is based on a field data collected through the administration of questionnaires about the state of deterioration of in-service buildings in the government residential estate that used paint as external finish in Ibadan under forest climatic zone for architectural design in Nigeria. The study adopted stratified random sampling technique as a result of the different types of housing units that were within the housing estate. The estate was stratified based on the number of building typologies that were present and each sub-stratum was then randomly sampled and grouped into households. The heads of households were the basic focus of questionnaire administration. The research population was 1034 and a sample size of 118 was obtained using sample size calculator. The structured questionnaire dwelt on the characteristics of buildings that cause external paint degradation and the extent of defect shown on the surface was the dependent variable while the independent variables included building age, façade orientation, building layout, road proximity, nearness to water body, proximity to vegetation, proximity to industrial facilities, closeness of other buildings, wind effect, rain effect, surface preparation of the painted surface, paint type, colour of paint applied, type of paint applied, number of storey height and portion of the defect. The step-by-step method was used to define the explanatory variables where the basic regression assumptions were revised and the variables that were not significant or explanatory of the dependent variables were excluded. Thirteen independent explanatory variables analysed using this model were age, façade orientation, distance to road, distance to river, distance to vegetation, surrounded by other buildings, effect of wind, rain effect, surface after repaint, type of paint used, colour of paint, number of storeys and portion of external surface where defect is shown. Residual statistics was then used to determine the service life of painted surfaces using SPSS (Statistical Package for Social Science, version 16).

Study area

The study area chosen for this study is Bodija Housing Estate in Ibadan, the capital of Oyo State. Ibadan as shown in figure 1 is located in south-western Nigeria in the south-eastern part of Oyo State at about 119 kilometres (74 miles) northeast of Lagos and 120 kilometres (75 miles) east of the Nigerian international border with the Republic of Benin. It lies completely within the tropical forest zone but close to the boundary between the forest and the derived savanna. The city ranges in elevation from 150m in the valley area, to 275m above sea level on the major north-south ridge which crosses the central part of the city. The city covers a total area of 3,080 square kilometres (1,190sq mi), the largest in Nigeria (Akinsanola and Ogunjobi, 2014). Ibadan has a tropical wet and dry climate (Koppen, 1918), with a lengthy wet season and relatively constant temperatures throughout the course of the year. Ibadan's wet season runs from March through October, although August sees somewhat of a lull in precipitation. This lull nearly divides the wet season into two different wet seasons. November to February forms the city's dry season, during which Ibadan experiences the typical West African harmattan. The mean total rainfall for Ibadan is 1420.06 mm, falling in approximately 109 days. There are two peaks for rainfall, June and September. The mean maximum temperature is 26.46°C; mean minimum temperature is 21.42 °C and the relative humidity is 74.55%.

RESULTS AND DISCUSSION

This study has adopted the variables that have been validated in past studies. The use of inferential statistical model that was further supported with experts' opinion provided gave an insight on the building characteristics that caused degradation of external paint finish. The building characterized and regression analysis was carried out to estimate the factors responsible for the extent of defects of external paint finish. Accordingly, the dependent variable which measures the extent of defect of external paint finish was rated 1 if the respondent perceives the extent of the defects as no visible defects, 2 when the defects exhibit few signs, 3 as general defects and 4 as severe defects. A total of sixteen predictor variables was fed into the model. Table 1 shows the regression coefficients of the building characteristics responsible for the extent of defects of external paint finish. The coefficients are based on scale model, which depends on the main and interaction effects. The table revealed that building characteristics of age (β =.271, t = 1.05; p < .05), facade (β =.229, t = 0.78; p < .05), distance to road (β =.012, t = 0.02; p < .05), distance to river (β =.067, t = .15; p < .05), distance to vegetation (β =-.206, t =-0.92; p < .05), number of surrounded building (β =-.744, t = -1.09; p < .05), wind effect (β =1.419, t = 1.72; p < .05), rain effect (β =-1.276, t =-1.61; p < .05), surface after repaint (β =-6.353, t = -3.19; p < .05), type of paint used (β =-.967, t = -1.36; p < .05), colour of paint (β =-.084, t = -0.12; p < .05, number of storeys (β =-.185, t = -0.24; p < .05), and portion of defect (β =-2.73, t = -5.06; p < .05), had independent significant prediction on external paint degradation. However, layout (β =-.061, t = .009; p > .05), paint application (β =.496, t = 0.63; p > .05), and distance to industry (β =-.005, t =- 0.02; p > .05), did not significantly and independently predict external paint degradation.

Table 1. Summary of Ordinal Regression Analysis Showing the Effects of Building Characteristics on External Paint Degradation

Variables	β	t	ρ	ρ
Age	.271	1.05	.052	ρ <.05
Façade orientation	.229	0.78	.003	ρ <.05
Layout	.061	0.09	.085	ρ > .05
Distance to road	.012	0.02	.009	ρ <.05
Distance to river	.067	0.15	.007	ρ <.05
Distance to vegetation	-.206	-0.92	.040	ρ <.05
Distance to industry	.005	0.02	.241	ρ >.05
Surrounded by buildings	-.744	-1.09	.009	ρ <.05
Wind effect	1.419	1.72	.005	ρ <.05
Rain effect	-1.276	-1.61	.001	ρ < .05
Surface after repaint	-6.353	-3.19	.012	ρ <. 05
Type of paint used	-.967	-1.36	.017	ρ <.05
Colour of paint	-.084	-0.12	.004	ρ <.05
Paint application	.496	0.63	.521	ρ >.05
Number of storeys	-.185	-0.24	.008	ρ <.05
Portion of defect	-2.73	-5.06	.000	ρ <.05

[The result ρ = 0.0000 < .05], R^2 = .8172 implied that 82% of the variance in the degradation of external paint finish is accounted for by the selected independent explanatory variables of age, façade, distance to road, distance to river, distance to vegetation, number of surrounded building, wind effect, rain effect, surface after repaint, type of paint used, colour of paint, number of storey, and portion of defectusing this model were as shown in Table 2. The step-by-step (Stepwise) method used to define the explanatory variables. In this method, the basic regression assumptions were revised and the variables that were not significant or explanatory of the dependent variables were excluded. According to Leung et al (2001), the multicollinearity effects were also eliminated. Linear regression allows identifying the characteristics that influence the durability of paintings and also establishes a hierarchical distinction between the different characteristics, evaluating which variables are more relevant to the degradation of painted surfaces. The model presents a very strong correlation between variables, deemed appropriate to model the durability of painted surfaces. Thirteen independent explanatory variables analysed using this model were façade orientation, distance to the river, the effect of wind, type of paint used, colour of paint and portion of external surface where the defect is visible as shown in Table 2. The statement is incomplete. The complete statement is 'The result which is statistically significant at 0.05(95%) confidence interval indicates that as the ratings of the building increase, the extent of defects of external paint finish increases. The table reveals that building characteristics of wind effect, colour of paint, age of building, rain effect, distance to river, façade, paint application, type of paint and portion of defect had significant prediction on external paint degradation in the selected estate. Table 3 shows the residual statistics of the multiple linear regression for the predicted service life in Bodija Housing Estate, Ibadan, while table 4 provides the summary of the statistical indicators for the reference service life estimated, which includes a maximum value, a minimum value, a range and a standard deviation of the reference service life for the coastal design climatic zone of Nigeria. The estimated reference service life in the forest climatic design zone of Nigeria is (5 years) given by this model. The minimum reference service life is 3 years, the maximum reference service life is 5 years while the average service life is 5 years.

Table 2. Summary of regression analysis showing the effects of defect factors on external paint degradation

Variables	Coef	Z	ρ	Pseudo R^2	ρ
Age	.271	1.05	.052		
Façade orientation	.229	0.78	.003		
Distance to road	.012	0.02	.009		
Distance to river	.067	0.15	.007		
Distance to vegetation	-.206	-0.92	.040		
Surrounded by buildings	-.744	-1.09	.009		
Wind effect	1.419	1.72	.005		0.000
Rain effect	-1.276	-1.61	.001	0.8172	
Surface after repaint	-6.353	-3.19	.012		
Type of paint used	-.967	-1.36	.017		
Colour of paint	-.084	-0.12	.004		
Number of storeys	-.185	-0.24	.008		
Portion of defect	-2.73	-5.06	.000		

Table 3. Residuals Statisticsof the multiple linear regression for the predicted service life in Bodija Housing Estate, Ibadan, Oyo State (Forest Zone)

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	3.15	5.23	4.55	.611	118
Std. Predicted Value	-2.297	1.112	.000	1.000	118
Standard Error of Predicted Value	.102	.250	.138	.028	118
Adjusted Predicted Value	3.04	5.29	4.55	.612	118
Residual	-3.320	2.811	.000	1.076	118
Std. Residual	-2.988	2.600	.000	.996	118
Stud. Residual	-3.017	2.615	.000	1.004	118
Deleted Residual	-3.293	2.844	.000	1.095	118
Stud. Deleted Residual	-3.129	2.684	-.002	1.013	118
Mahal. Distance	.068	5.277	.992	.878	118
Cook's Distance	.000	.088	.009	.014	118
Centered Leverage Value	.001	.045	.008	.008	118

Maintenance guilde for paints in forest region

Table 5 shows that the cost of maintenance in 5 years after the completion of the building is ₦1116.68 /m^2 using the inflation rate. The predicted value of ₦1116.68 /m^2 was discounted at an interest rate of 12% and the present value is ₦633.60/m^2.

Table 4. Summary of the statistical indicators for the reference service life estimated using the proposed multiple linear regression model life in Bodija Housing Estate, Ibadan, Oyo State (Forest Zone)

Statistical Indicator	Values (Years)
Average of the reference life	4.55
Maximum reference service life	5.23
Minimum reference service life	3.15
Range of reference service lives	2.08
Standard deviation of the reference service life	.611
Variance of the reference service life	.8

The implication is that for 1 metre square of an area to be maintained in 5 years to come, the sum of ₦633.60 will required to be saved by the building owner for the façade. Thus, for a total surface of say 10 square metres, it will require (633.60 x 10) to be saved by the owner to repaint the wall in 5 years' time. This will also apply for 10, 15, and 20 years projections. For the study, the present-value of the maintenance plan over a period of 20 years is thus determined as maintenance every 5 years in accordance with the results obtained in terms of the paint estimated service-life.

In Nigeria, theconsumer price index (CPI) is calculated monthly by the National Burau of statistics, based on monthly expenditure on food, housing, education, health, transport, and so on. In this study, a discounted rate of 12% is adopted for the cost differential rate, an average computed by the CBN between 1980-2015 is 11.38%. The difference between CPI of one month in a preceding year over the CPI of the same month in the current year is known as inflation rate. Based on this, the average inflation rate computed between 2001-2005 is 0.27, 2006-2010 is 0.52 and 2011-2015 is 1.03 from the information supplied by Nigeria Historical inflation rate 2006-2017. This implies that the inflation rate doubles at every 5 years. Therefore, for this study, the inflation rate between 2010-2015 was used as the basis to project the inflation rate for the next 20 years.The repair and maintenance costs presented in Table 5 were calculated with the help of a Quantity Surveyor in accordance with Nigerian reality. Paint in most cases in Nigeria is applied on rendered surfaces. Therefore, its removal may aggravate their degradation. Due to this, repair of the renderings needs to be well thought-out every time paint is removed. In the maintenance plan being considered, it is expected that rendering is removed at the expiration of the life of the building.

Table 5. Cost of the Maintenance Works

Periodicity (Years)	Maintenance Actions	Cost in year 0 (₦/m^2)	Current cost (/₦m^2)	Present Value (₦/m^2)
5	Material (Paint)	833.78		
	Scaffolding	72.52		
	Labour	108.78	1116.68	633.60
	Profit and Overhead	145.04		
10	Material (Paint)	833.78		
	Scaffolding	72.52		
	Labour	108.78	3300.36	740.72
	Profit and Overhead	145.04		
15	Material (Paint)	833.78		
	Scaffolding	72.52		
	Labour	108.78	4600.72	840.55
	Profit and Overhead	145.04		
20	Cleaning and Repair	54.39		
	Material (Paint)	833.78		
	Scaffolding	72.52		
	Labour	108.78	10.343.67	1072.64
	Profit and Overhead	192.14		

Conclusion

The proposed model was based on the statistical tool that has been used in a wide range of knowledge areas. In this study, regression analysis was used to determine the influence of various variables in explaining degradation severity. It was found that the average service life of external paint coatings values estimated in the forest climatic zones of Nigeria is 5 years with this model. The minimum reference service life is 3 years while the maximum reference service life is 5 years. However, the result is in agreement with the findings of Folorunso, (2014) and Aluko (2018) who had established the service life of paint in coastal and savannah zones in Nigeria between 4-5 years. The results of the findings also negate the lifespan of paint used as external finish in other climatic regions different from the tropical environment in Nigeria which puts the lifespan of buildings in temperate region between 7- 10 years. This corroborates the results of Aluko (2018) that external surfaces of building enclosures and its coatings are directly affected by climate and that different climatic condition imposes different nature of defects on the external finishes. The residual service life of building elements is not only used as a decision criterion in maintenance and refurbishment scenarios but is also an important factor in Life Cycle Analysis. The generated maintenance guide is a valuable information for investment planning as it helps the owner of buildings to decide the moment when maintenance works will be undertaken in line with available financial capability.

REFERENCES

Akinsanola, A. and Ogunjobi, K. 2014. Analysis of rainfall and temperature variability over Nigeria. *Global Journal of Human Social Science*, 4, pp. 1-18.

Aluko, O. O. 2018. Degradation of external paint finish in different climatic design zones of Nigeria. PhD Thesis, School of Environmental Technology, Federal University of Technology, Akure.

Anoop, M. B., Raghuprasad, B. K.; Balaji Rao, K. 2012. A refined methodology for durability-based service life estimation of reinforced concrete structural elements considering fuzzy and random uncertainties, *Computer-Aided Civil and Infrastructure Engineering,* 27(3), pp. 170–186.

Aosmohor, A. 2010. Managing in the Historic Environment: External Walls. Historic Scotland.

Available on www.historic-scotland.gov.uk/externalwalls.

Chai, C. 2011. *Service life prediction of painted surfaces in external walls*, Master Dissertation in Civil Engineering, Instituto Superior Técnico, Technical University of Lisbon, Portugal. (In Portuguese).

Chai, C., de Brito, J., Gaspar, P. L. and Silva, A. 2014. Predicting the service life of exterior wall painting: Techno-economic analysis of alternative maintenance strategies, *Journal of Construction Engineeringand Management,* 140 (3), pp. 04013057

Chew, M.Y. L., Tan, S. S. and Kang, K. H. 2004. Building maintainability. J ArchitEng, ASCE. pp. 80–87.

Christian, A. L., Svein B. and Per J. H. 2011. Service life estimation of facades - use of the factor method in practice. *International Conference on Durability of Building Materials and Components,* Portugal. April 12th – 15th.

Construction Technology. *The Technology of Refurbishment and Maintenance, New York.* (3),pp. 50 – 56.

Fawehimi, A, S. and Adeosun, T. 2001. The growing syndrome of unpainted houses in Akure peripheral suburb. *Journal of Industrial Design and Technology*, 2 (2), pp. 32-39.

Flourentzou, F., Brandt, E., Wetzel, C. 1999. MEDIC – a method for predicting residual service life and refurbishment investment budgets, in *8th International Conference on the Durability of Building Materials and Components (DBMC)*, Ottawa, Canada, pp. 1280–1288

Folorunso C. O. 2014. Building exterior paint performance in tropical salty environment of Lagos. PhD Thesis, Faculty of Built Environment, University of Technology, Malaysia.

Gaspar, P. de Brito, J. 2008. Quantifying environment effects on cement-rendered facades: a comparison between different degradation indicators, Building andEnvironment 43 (11), pp.1818–1828.

Gaspar, P. 2009. Service life of constructions: development of a method to estimate the durability of construction elements. Application to renderings of current buildings, Doctor Thesis in Sciences of Engineering.Instituto Superior Técnico, Technical Universityof Lisbon, Portugal.

Gaspar, P.; de Brito, J. 2008. Service life estimation of cement-rendered facades, *Building Researchand Information* 36 (1),pp. 44–55.

Hermans M. 1995. Deterioration of building components. A data collecting model to support performance management. PhD Thesis. Faculty of architecture and building science, Eindhoven, University of Technology;

Hovde, P. 2004. Factor methods for service life prediction, in: CIB W080/RILEM 175SLM: Service Life Methodologies Prediction of Service Life for Buildings and Components, Task Group Performance Based Methods of Service Life Prediction,Trondheim, Norway, pp. 1–51.

International Standardisation Organisation (ISO) ISO 15686-1:2000 *Building and constructed assets: Servicelife planning – Part 1: General principles*. International Standard Organization, Geneva.

Köppen, Wladimir, 1918. "Klassification der Klimatenach Temperatur, Niederschlag and Jahreslauf". Petermanns Geographische Mitteilungen. (64), pp. 193–203.

Lacasse, M. A., Sjöström, C. 2004. Recent advances in methods for service life prediction of buildings materials and components – an overview, in *CIB World Building Congress*, Canada, pp. 1–10.

Long, A. E.; Henderson, G. D.; Montgomery, F. R. 2001. Why assess the properties of near-surface concrete?*Construction and Building Materials,* 15(2–3),pp. 65–79.

Masters, L. W.; Brandt, E. 1987. Prediction of service life of building materials and components. RILEM Technical Committee, CIB W80/RILEM 71-PSL Final Report, *Materials and Structures,* 20, pp. 55–77.

Mejri, M. Cazaguel, M. Cognard, J.Y. 2010. A time-variant reliability approach for ageing marine structures with non-linear behavior, *Computers and Structures,* 89 (19–20),pp. 1743–1753.

Moser, K. (2004). *Engineering design methods for service life prediction*. CIB W080 / RILEM 175 SLM: Service Life Methodologies Prediction of service life for Buildings and Components, Task Group: Performance based methods of service life prediction, Trondheim, Norway, pp. 52–95.

Onibokun, P. O. and Agboola, T. A. 1991. Urban housing problems: implication for construction industry in Nigeria. *Urban Housing in Nigeria*, Nigerian Institute of Social and Economic Research, NISER, Ibadan, pp. 1- 16

Riky, M. and Cotgrave, A. 2005. The context of maintenance. In: Macmillan Palgrave, editor.

Shohet, I. and Paciuk, M. 2004. Service life prediction of exterior cladding components under standard conditions, *Construction Management and Economics,* 22(10), pp. 1081–1090.

Shohet, I. M., Puterman, M. and Bilboa, E. 2002. Deterioration patterns of building cladding components for maintenance management, *Construction Management and Economics* 20 (4), pp. 305–314.

Shohet, I. Rosenfeld, Y. Puterman, M. and Gilboa, E. 1999. Deterioration patterns for maintenance management — a methodological approach, in: 8th DBMC, International Conference on the Durability of Building Materials and Components; Ottawa, Canada, pp. 1666–1678.

Silva, A., de Brito, J., Gaspar, P. 2012. Application of the factor method to maintenance decision support for stone cladding, *Automation in Construction,* 22: pp. 165–174.

Silva, A., Dias, J. L., Gaspar, P., de Brito, J. 2013. Statistical model applied to service life prediction of rendered façades, *Automation in Construction,* 30, pp. 151–160.

Yiu, C. Y. 2008. Intelligent building maintenance- A novel discipline. *Journal of Building Appraisal*, *3* (4), pp.306-317.

****