IDENTIFICATION OF THE UNCERTAIN EVENTS IMPACTING ON CONSTRUCTION TIME OF SOUTH AFRICAN HIGHWAY PROJECTS

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ABSTRACT

This article examines the uncertain events encountered in the construction process of highway projects in South Africa, so as to evaluate their impact on the construction time of such projects. The rationale for this examination stems from the view held by scholars that highways are complex projects initiated in dynamic environments, which are often beset by different uncertainties and a lack of appropriate evaluation of the uncertain events that occur during the construction process. The research made use of a review of existing literature in the area of uncertainty management and modelling in infrastructure projects, to guide the direction of the study, brainstorming, and interviews conducted with highway experts to identify the factors of uncertainty that impact construction time on infrastructure projects. A simple uncertainty matrix for South African highway projects was developed using a quantitative model and descriptive statistics. It emerged from the study that the uncertain events that affect the construction time of highway projects are distributed across economic, environmental, financial, legal, political, social and technical factors. Also, it was found that each factor contains several uncertain events, which impact on construction time differently, through a combination of the uncertain events of the individual construction activities. Based on the findings, it can be concluded that construction time on South African highway projects is significantly related to the social and technical factors of uncertainties. The matrix developed will be useful in modelling uncertainty of the cost and time of individual construction activities in highway projects.

Keywords: construction time, highway projects, South Africa, uncertainty

1. INTRODUCTION

Highway construction projects are subject to risks and uncertainties (Moret and Einstein, 2016). There are various risks and uncertainties existing in highway construction projects that affect construction performance differently. Risks have different probabilities of occurrence that impact project performance (Walker et al., 2003), causing schedule delays or cost overruns (Moghayedi, 2016; Chapman, 2006; Wang and Chou, 2003; Zayed and Halpin, 2004). The number and the importance of such events depend on the size and the complexity of the construction project (Zavadskas et al., 2010). Highway projects are one of the most dynamic, challenging, and complex construction projects, because they are exposed to different risks (Mills, 2001). According to Flyvbjerg (2007), there is more uncertainty in highway projects than there is in other construction projects, because of the unique features of such projects, including complexity in the long duration of the construction, the dynamic nature of the process, the repetitive linear nature of such projects, and the mobile nature of the construction sites. Uncertainty affecting construction projects has long been recognised by researchers as a major obstacle to achieving the objectives of the project, and as a cause of low levels of productivity (Antunes and Gonzalez, 2015; Bloom, 2014; Childerhouse and Towill, 2004; Moret and Einstein, 2016).

Uncertainty means an unknown phenomenon (Walker et al., 2003). It is associated with the location, it is project-specific, and it has no root causes that can be generalised (Ramanathan et al., 2012). Therefore, there is an obvious need to effectively anticipate, identify and classify the uncertain events on different locations and projects to assess their influence on the objectives of construction projects. Uncertainty assessment involves identifying, evaluating and modelling various uncertain events in the construction process of highway projects, and developing a model for quantifying the impact of different events on the objectives of the project.

The magnitude of the influence of uncertainty can be assessed by two parameters, namely probability of occurrence, and severity of the event (Gadd et al., 2003; ISO, 2009; Project Management Institute, 2013). Quantification of these factors with classical methods, such as probability analysis and influence diagrams, is very difficult (Zeng et al., 2005). Efficient applications and quantification techniques are difficult and complex, and, furthermore, exact data are required (Winch, 2010). Unfortunately, such data either do not exist at all or are hard to obtain. Furthermore, most of the classical mathematical assessment methods, such as differential equations, are not able to examine the relationship between input variables and an output variable, and they are not well suited for uncertain problems (Youssef, 2004). Stepwise regression analysis (SRA), on the other hand, is used in modelling to examine the strength and the direction of the relationship between each dependent variable and an independent variable, and the results indicate whether this relationship is statistically valid. Also, SRA is able to estimate the value of dependent variable when the independent variables are known.

Therefore, this current research examines the uncertain events in the construction of highway projects in South Africa, and whether there are key events that have a significant impact on the completion time of such projects, with the aim of developing SRA models to assess the impact of uncertainty on the completion time of highway construction projects.

2. LITERATURE REVIEW

The effect of uncertain events on the objectives of infrastructure projects has been identified in several works of literature (Anderson et al., 2007; Antunes and Gonzalez, 2015; Barker and Haimes, 2009; Moret and Einstein, 2016; Renuka et al., 2014). Occurrence of uncertain events in highway construction projects is greater than in other construction projects, due to the unique features of such projects, including complexity, the long duration of the construction, the dynamic nature of the process, the repetitive linear nature of such projects, and the mobile nature of the construction sites (Flyvbjerg, 2007). Due to the peculiar nature of uncertainty, there is a need to identify and classify the uncertain events and their factors, using the breakdown structure and the risk and uncertainty management process to assess their impact.

One of the most comprehensive studies in the field of uncertainty factors identification was conducted by Aziz and Abdel-Hakam (2016). They explored 293 disruptive events as delay causes of road construction projects in Egypt under 15 major groups. Another noteworthy study was conducted by Odediran and Windapo (2017). They identified 81 risks in African construction markets under five major factors, namely political, social, economic/financial, procurement, and design and construction. Similarly, Assaf and Al-Hejji (2006) evaluated 73 uncertain events that cause delays in different types of large construction projects in Saudi Arabia under the following factors: project, owner, contractor, design, materials, equipment, labour, and external.

After an extensive review of literature in the field of risk and uncertainty in construction projects, the seven uncertainty-related factors most common to researchers in the field were identified. They are presented in Table 1.

Table 1: Proposed uncertainty factors

Factor	Description	Sources
Economic	Issues or concerns associated with the macroeconomic impact of the community and the region in which the construction project is to be located	Banaitiene and Banaitis, 2012; Dey, 2001; Iyer and Jha, 2005; Kuo and Lu, 2013; Saqib et al., 2008; Tah and Carr, 2000; Wang and Yuan, 2011; Zavadskas et al., 2010
Environmental	Issues associated with the environmental problems, concerns and activities confronting the project	Banaitiene and Banaitis, 2012; Ehsan et al., 2010; Iyer and Jha, 2005; Saqib et al., 2008; Tah and Carr, 2000; Wang and Yuan, 2011
Financial	Issues or concerns associated with the financing of the project. Several researchers emphasise financial uncertainties as one of the important factors affecting infrastructure project outcomes	Banaitiene & Banaitis, 2012; Bunni, 2003; Dey, 2001; Ehsan, Mirza, Alam, & Ishaque, 2010; Fang, Marle, Zio, & Bocquet, 2012; Saqib, Farooqui, & Lodi, 2008; Shen, Wu, & Ng, 2001; Taghipour, Seraj, Hassani, & Kheirabadi, 2015; Tah & Carr, 2000; Zayed, Amer, & Pan, 2008
Legal	Issues or concerns associated with the significant legal consequences that flow from legal actions attributable to the project	Bunni, 2003; Shen et al., 2001; Zou et al., 2007
Political	Issues or concerns associated with the local, regional and national political and regulatory situation confronting the project. Various researchers identify political uncertainty as a major factor affecting the	Baloi and Price, 2003; Banaitiene and Banaitis, 2012; Dey, 2001; Ehsan et al., 2010; Iyer and Jha, 2005; Saqib et al., 2008; Taghipour et al., 2015;

	performance of infrastructure projects.	Tah and Carr, 2000; Zavadskas et al., 2010; Zayed et al., 2008
Social	Issues or concerns associated with the social and cultural impacts of the community and the region in which the construction project is to be located	Kuo and Lu, 2013; Saqib et al., 2008; Wang and Yuan, 2011; Zavadskas et al., 2010
Technical	Issues or concerns associated with the technology used in the project by different stakeholders during construction	Banaitiene and Banaitis, 2012; Bunni, 2003; Dey, 2001; Dikmen et al., 2007; Ehsan et al., 2010; Fang et al., 2012; Mahendra et al., 2013; Nieto-Morote and Ruz-Vila, 2011; Saqib et al., 2008; Shen et al., 2001; Tah and Carr, 2000; Wang and Yuan, 2011; Zavadskas et al., 2010; Zayed et al., 2008

Through a review of the literature, a list of uncertain events that impact on the completion time of construction projects was compiled. These events were analysed and ranked according to the number of times cited. The top 20 uncertain events cited in the literature which were adapted to the current study are listed in Table 2.

Table 2: Top 20 uncertain events cited in the literature

Event	Factor	Adam et al. (2017)	Odediran and Windapo (2017)	Santoso and Soeng (2016)	Aziz and Abdel-Hakam (2016)	Taghipour et al. (2015)	Marzouk and El-Rasas (2014)	Mahendra et al. (2013)	Banaitiene and Banaitis (2012)	Fang et al. (2012)	Kuo and Lu (2013)	Nieto-Morote and Ruz-Vila (2011)	Ehsan et al. (2010)	Zayed et al. (2008)	Saqib et al. (2008)	Zou et al. (2007)	Assaf and Al-Hejji (2006)	Dey (2001)	Total
Weather	Environ-mental	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Availability of materials	Technical	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	15
Inaccurate management or supervision	Technical		✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	14
Availability of skilled labour	Technical	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓		✓	✓	✓	✓	14

Health & safety	Technical	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓	✓		13
Materials delivery	Technical			✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	12
Construction methods	Technical	✓		✓	✓	✓	✓		✓	✓	✓		✓	✓	✓		✓		12
Availability of equipment	Technical		✓	✓	✓		✓		✓	✓		✓	✓		✓	✓	✓	✓	12
Cash flow difficulties (contractor finance)	Financial	✓	✓	✓	✓		✓	✓	✓		✓	✓		✓	✓		✓		12
Design, drawings, specifications, and samples	Technical		✓	✓	✓	✓	✓		✓	✓			✓		✓	✓	✓		11
Incompetent contractor/ subcontractor	Technical			✓	✓	✓	✓		✓	✓			✓		✓	✓	✓		10
Low level of productivity	Technical			✓	✓	✓	✓		✓	✓			✓		✓	✓	✓		10
Payment delays	Financial	✓	✓		✓		✓	✓	✓		✓	✓		✓			✓		10
Planning and scheduling of project by contractor	Technical		✓		✓	✓	✓		✓	✓			✓		✓	✓	✓		10
Difficulty of schedule	Technical				✓	✓	✓		✓	✓			✓		✓	✓	✓		9
Lack of capital by owner	Financial	✓	✓		✓		✓	✓			✓	✓		✓			✓		9
Change order (change in the scope of the project)	Technical		✓		✓	✓			✓	✓			✓		✓	✓		✓	9
Legal/ industrial disputes between various parties in the construction project	Legal	✓			✓		✓	✓			✓		✓		✓		✓		8
Communi-cation/ coordination between construction parties	Technical				✓	✓			✓	✓			✓		✓	✓		✓	8
Fluctuation of prices of	Economic	✓	✓		✓			✓			✓	✓		✓			✓		8

materials and/or equipment

It can be seen from Table 2 that the most cited uncertain events are technical-related. To verify the existence of these uncertain events in highway construction projects in South Africa, the research conducted further investigations. The methods used are presented in the following section.

3. RESEARCH METHODOLOGY

The study made use of a sequential mixed-methods research approach in identifying the uncertain events and their main factors and assessing the impact of uncertainties on the completion time of highway construction projects in South Africa. Brainstorming sessions were held with six highway experts who have more than 25 years of experience in South African highway construction projects. The highway expert panel reviewed and modified the uncertain events identified in the literature to appropriately reflect the events occurring on South African highway construction projects. The expert panel also grouped these events into seven uncertainty factors, as seen in Table 1.

A survey questionnaire was designed on a five-point linguistic Likert-scale form to assess the impact size of confirmed uncertain events in highway construction projects in South Africa. The questionnaire was administered to 32 highway project managers with a minimum of 20 years of experience in the South African construction industry, to rate the probability of occurrence and the severity of each uncertainty on the completion time of a highway project.

4. DATA ANALYSIS

To evaluate the effect of uncertainties on construction time of highway projects using collected data on the probability of occurrence and the severity of uncertainties from the six highway experts, the ISO (International Standards Organization) 31000 impact matrix was utilised (ISO, 2009). The ISO (2009) defined the impact size of an event as a function of the probability of occurrence and the severity of that event should it occur.

Table 3 shows the probability of occurrence and the severity as two input variables, and relevant impact size as the output variable.

Table 3: Impact size matrix

		Severity				
		Insignificant (1)	Minor (3)	Moderate (5)	Major (7)	Catastrophic (9)
Probability of occurrence	Rare (.1)	Minimal	Minimal	Low	Low	Moderate
	Unlikely (.3)	Minimal	Low	Moderate	Moderate	High
	Possible (.5)	Low	Moderate	Moderate	High	High
	Likely (.7)	Low	Moderate	High	High	Extreme
	Almost certain (.9)	Moderate	High	High	Extreme	Extreme

4.1 Developing a stepwise regression model

The main objective of this study is to quantitatively analyse and assess the impact of uncertainties on completion time of highway construction projects, through numerical analysis of the uncertainty variables. Stepwise regression analysis (SRA) is an extension of multiple regression analysis. The SRA model is a mathematical model used in estimating the relationship between a dependent variable and independent variables, with a strong mathematical background. SRA models have been used extensively in different areas of construction management, particularly assessing risk and uncertainty, assessing the critical factors affecting cost performance of Ethiopian public construction projects (Sinesilassie et al., 2018), modelling the construction risk ratings and estimating contingencies in highway projects (Diab et al., 2017), identifying the success factors for public-private partnership projects in Korea (Yun et al., 2015), evaluating project risks in Iran (Ebrat and Ghodsi, 2014), evaluating the risk factors leading to cost overruns in highway construction projects in Australia (Creedy et al., 2010), analysing the risk perception of build-operate-transfer road project participants in India (Thomas et al., 2003), developing models to forecast the actual construction cost and time (Skitmore and Ng, 2003), and designing a multivariate analysis to build project success factors in Hong Kong (Chan et al., 2001).

The impact size of uncertain events as the dependent variable is a function of two independent variables (probability of occurrence, and severity) of relative uncertainty (ISO, 2009), as shown in Equation 1.

$$Uncertainty\ impact_i = a_i p + b_i s + r_i \qquad \text{(Equation 1)}$$

Where r_i is a constant value. a_i and b_i represent regression coefficients of the independent variables.

Because each input variable can have a low correlation with the output variable, the SRA model was used in this study. Table 4 presents the values of the correlation coefficients.

Table 4: Correlation coefficients among the input and output variables

	Probability	Severity	Impact
Probability	1		
Severity	0	1	
Impact	0.685061	0.685061	1

Table 4 shows the low correlation between the independent variables and the dependent variable.

The general SRA model for impact size, based on the impact size matrix in Table 3, has been developed to predict the impact size of each uncertainty on cost and time of highway construction projects. The SRA model test details are shown in Table 5.

Table 5: Regression test details

Regression statistics	
Multiple R	0.968822
R-squared	0.93861607
Adjusted R-squared	0.93303571
Standard error	0.31622777

	Coefficient	Standard error	*t*-statistic	P-value
Intercept	0.18	0.170294	1.056996	0.301982
Probability	2.9	0.223607	12.96919	8.82E-12
Severity	0.29	0.022361	12.96919	8.82E-12

Table 5 reveals that the correlation value (R-Squared) of the model is close to 1, and the P-value is very low (<0.05). The very low P-value indicates the statistically significant relationship of each independent variable to the dependent variable of the model, and the closeness of the R-value to 1 verifies the close fit of the estimated output model to real data. The developed stepwise regression analysis model for general uncertainty impact size is outlined in Equation 2.

$$Uncertainty\ impact = 2.9 \times p + 0.29 \times s + 0.18 \qquad \text{(Equation 2)}$$

Similar steps were repeated to develop the SRA models for each uncertainty impact on construction time of highway projects. To assess the optimum impact size of each uncertainty, the optimum values of two independent variables (probability of occurrence, and severity of event) are identified using sensitivity analysis, and are inserted to develop the SRA models. For instance, the maximum probability of occurrence (0.6625) and severity (5) value of event weather were inserted to develop the SRA model (Y = 0.2915 + 2.9728p + 0.27905s), and the estimated impact size of this uncertainty (3.66) on the completion time of highway construction projects. The impact sizes of all identified uncertainties on the completion time of highway construction projects were estimated and ranked. Table 6 presents the top 20 events with significant impact size on construction time of highway projects, from a ranking perspective.

Table 6: Top 20 uncertain events with significant impact size on construction time of highway projects

Code	Event	Probability of occurrence	Severity of event	Impact size	Rank
TG11	Latent ground conditions	0.84375	8.3125	4.94	1
TCS6	Inaccurate time and cost estimation	0.79375	8.3125	4.78	2
TG5	Inadequate planning and scheduling of project by contractor	0.8125	7.6875	4.72	3
SO4	Rehabilitation of affected people	0.78125	7.8125	4.66	4
PL3	Human-made disaster (war, protest, strike, etc.)	0.8125	7.4375	4.66	5
SO5	Disease (HIV, Ebola, etc.)	0.70625	6.8125	4.19	6
TG9	Change order by owner (scopes and specifications)	0.73125	6.4375	4.16	7
TG4	Difficulty of schedule	0.55625	7.75	4.00	8
TCR5	Rework due to contractor errors	0.64375	5.5625	3.84	9
EN2	Natural disasters (earthquake, floods, hurricane, etc.)	0.4125	7.9375	3.81	10
SO3	Social and cultural impacts	0.76875	4.375	3.81	11
TT1	Obsolete technology	0.58125	6.1875	3.78	12
LE9	Problem in dispute settlement due to law	0.625	5.6875	3.78	13
TCR4	Management or supervision of project by contractor	0.66875	5.5	3.78	14
TL1	Low level of productivity	0.725	4.625	3.75	15
TM2	Materials delivery	0.56875	6.1875	3.75	16
TCS4	Design, drawings, specifications, and samples	0.675	5.1875	3.75	17
PL1	Political situation	0.64375	5.6875	3.72	18
TCS3	Frequent design changes	0.60625	5.8125	3.72	19
TM3	Bad quality of materials	0.61875	5.5	3.72	20

It can be seen from Table 6 that the top three uncertain events, based on estimated impact on completion time of highway construction projects, from a ranking perspective, are latent ground conditions (4.94), inaccurate time and cost estimation (4.78), and inadequate planning and scheduling (4.72). Likewise, latent ground conditions and inaccurate time and cost estimation are two uncertain events with catastrophic consequences.

To evaluate the SRA models' performance, the root-mean-square error (RMSE), the mean absolute percentage error (MAPE), and the R-squared of 76 developed assessment models were calculated. The results for the top 20 events in South Africa are presented in Table 5.

Table 5: Performance evaluation of the SRA models for the top 20 events

Code	Model	P-value	R-squared	RMSE	MAPE
TG11	Y = 2.9897 + 1.604p + 0.071255s	2.21e-10	0.784	0.244	0.0638
TCS6	Y = 1.3931 + 1.9967p + 0.21694s	1.01e-07	0.671	0.249	0.0481
TG5	Y = 0.89851 + 2.3235p + 0.25137s	3.56e-08	0.694	0.261	0.0533
SO4	Y = 0.5412 + 2.6448p + 0.26225s	7.5e-09	0.725	0.262	0.0537
PL3	Y = 0.80427 + 2.7748p + 0.21478s	3.7e-09	0.738	0.255	0.0518
SO5	Y = 0.064987 + 2.9907p + 0.29509s	2.85e-12	0.84	0.245	0.0521
TG9	Y = 0.88561 + 2.6217p + 0.21025s	2.1e-08	0.705	0.252	0.0556
TG4	Y = 0.88358 + 2.4275p + 0.22789s	2.21e-08	0.703	0.248	0.0557
TCR5	Y = 0.97812 + 2.1685p + 0.26421s	1.05e-06	0.613	0.237	0.0553
EN2	Y = 1.2336 + 2.0528p + 0.21823s	6.52e-07	0.626	0.251	0.0621
SO3	Y = 1.4539 + 1.8779p + 0.20912s	1.74e-07	0.658	0.24	0.0571
TT1	Y = 0.68305 + 2.7031p + 0.24679s	3.56e-09	0.739	0.259	0.0664
LE9	Y = 0.52521 + 2.481p + 0.29985s	1.55e-07	0.661	0.253	0.0628
TCR4	Y = 1.2381 + 2.0753p + 0.21005s	1.52e-07	0.661	0.253	0.0632
TL1	Y = 0.75 + 2.3438p + 0.28125s	2.25e-08	0.703	0.286	0.0729
TM2	Y = 0.98332 + 2.0923p + 0.25482s	6.62e-08	0.68	0.257	0.0660

TCS4	Y = 0.92489 + 2.6345p + 0.20179s	3.96e-08	0.691	0.253	0.0635
PL1	Y = 0.80167 + 2.2434p + 0.25897s	1.08e-08	0.718	0.251	0.0618
TCS3	Y = 0.92834 + 2.1309p + 0.25781s	2.62e-08	0.7	0.259	0.0669
TM3	Y = 0.24167 + 3.1541p + 0.27735s	1.54e-10	0.789	0.248	0.0620

The small value of errors (RMSE and MAPE) and P-values ($p<.01$) proved the reliability and statistical significance of all the developed models. However, the fit of the estimated values to real data varies from 0.442 to 0.954. Fifty-two of the developed models have a strong fit ($r>0.7$), 22 models have a moderate fit ($.5<r<.7$), and two of the models have a low fit to the real data (Moore and Kirkland, 2007).

Furthermore, the estimated impact size of uncertain events was classified into five groups, namely extreme, high, moderate, low, and minimal (see Table 7).

Table 7: Impact size groups

Group	Impact size	Events
Extreme	$I \geq 4$	Latent ground conditions; inaccurate time and cost estimation; inadequate planning and scheduling of project by contractor; rehabilitation of affected people; human-made disaster; disease; change order by owner; difficulty of schedule
High	$3 \leq I < 4$	Rework due to contractor errors; natural disasters; social and cultural impacts; obsolete technology; problem in dispute settlement due to law; management or supervision of project by contractor; low level of productivity; materials delivery; design, drawings, specifications, and samples; political situation; frequent design changes; bad quality of materials; security; new technology adoption; corruption; remote location cost; availability of skilled workers; availability of materials; change order; delays in decision-making; weather; right of way acquisition; payment delays; fluctuation of prices of materials and/or equipment; health & safety; financing by contractor, cultural heritage issues; inaccurate investigation of construction site; monopoly of material and/or equipment suppliers; low efficiency of equipment; unreliable supplier of material; lack of technical staff; mistakes in design and/or specifications; encroachment problems; lack of capital by owner; poor quality of workmanship; planning and scheduling of project by contractor; frequent change of subcontractors; contract failure – new contract establishment cost; terrain or topographical; construction methods; lack of technical staff; ineffective delay penalties; poor communication/coordination between construction parties

Moderate	2≤I<3	Absenteeism of labour; incompetent contractor/subcontractor; legal/industrial disputes between various parties in the construction project; changes in government regulations and laws; inadequate monitoring and supervision; poor financial control; type of contract; availability of equipment; deficient documentation; contractual claim; late delivery of equipment; personal conflicts among labour; lack of experience in the line of work; lack of experience in design and supervision; fluctuation in foreign exchange rate; high cost of materials and/or equipment; high tender price; changing of bankers' policy for loans; high cost of labour; saturated market; difficulties in importing equipment and materials
Low	1≤I<2	Slow mobilisation of equipment; tax and/or legal fees; size of contract
Minimal	1<I	NONE

Key: I = impact size

Table 7 groups the uncertain events identified in South African highway projects, based on their estimated impact on the completion time of projects.

5. DISCUSSION OF FINDINGS

The current study modelled the existing uncertain events in South African highway construction projects using stepwise regression analysis (SRA) to assess their impact on the completion time of such projects. Impact assessment of uncertain events is essential to prevent delays on the project before signs of delay begin to appear.

Comparison of the top 20 uncertain events from the literature review (see Table 2) with the 20 events with the highest estimated impact in South Africa (see Table 3) revealed that only seven events from this list are common with the top 20 cited events (inadequate planning and scheduling of project by contractor (3rd), change order by owner (7th), difficulty of schedule (8th), management or supervision of project by contractor (14th), low level of productivity (15th), materials delivery (16th), and design, drawings, specifications, and samples (17th)). The other 13 most-cited events are found to impact the construction time of highway projects differently (availability of skilled workers (25th), availability of materials (26th), weather (29th), payment delays (31st), fluctuation of prices of materials and/or equipment (32nd), health & safety (33rd), financing by contractor (34th), lack of capital by owner (43rd), construction methods (49th), poor communication/coordination between construction parties (52nd), incompetent contractor/subcontractor (54th), legal/industrial disputes between various parties in the construction project (55th), and availability of equipment (60th)).

The study found that more than 70% of identified events impact on the completion time of highway construction projects. The results presented in Table 7 revealed that eight uncertain events (10.5%) have an extreme impact on completion time of highway projects, 44 events (57.9%) have a high impact, 21 events (27.6%) have a moderate impact, and three events (4%) have a low impact on construction time of highway projects. This is evidence of the fact that the completion time of highway construction projects in South Africa is very sensitive to uncertain events. These results are consistent with those of previous studies. For instance, Adam et al. (2017), Assaf and Al-Hejji (2006), Aziz and Abdel-Hakam (2016), Baloi and Price (2003), Fang et al. (2012), Taghipour et al. (2015), Zayed et al. (2008), and Zou et al. (2007) also found that latent ground conditions was a key uncertain event impacting the construction time of projects.

Also, the SRA model results indicate that inaccurate time and cost estimation, inadequate planning and scheduling, changes to specifications, and difficulty of schedule are the other four technical uncertain events that extremely affect completion time of construction projects. These technical events were also identified in previous studies (Assaf and Al-Hejji, 2006; Aziz and Abdel-Hakam, 2016; Bunni, 2003; Ehsan et al., 2010; Gosling et al., 2012; Huang et al., 2002; Mahendra et al., 2013; Marzouk and El-Rasas, 2014; Saqib et al., 2008; Zou et al., 2007). Human-made disaster and disease emerged from the study as two political and social uncertain events with extreme impact on construction projects in South Africa, which is consistent with the findings of studies conducted by Aziz and Abdel-Hakam (2016), Marzouk and El-Rasas (2014), and Odediran and Windapo (2017) in South Africa and Egypt.

6. CONCLUSION

The current study adds to existing knowledge of construction management by including an extensive literature review in the field of uncertainty in construction projects, it established the uncertain events and uncertainty factors through brainstorming by a highway expert panel, and it verified the probability of occurrence and severity of 20 events through gathering data from highway construction experts. A significant number of the uncertainties were related to social and political factors. Therefore, it is recommended that the companies pursuing highway construction in African countries should seriously consider the social and political risks, along with the technical events, when involved in this market. The study also developed stepwise regression analysis models to assess the impact of each event on the completion time of highway construction projects, and it classified these events into five groups, based on their estimated impact.

This study is relevant to both practitioners and researchers. It provides practitioners with a simple and straightforward tool to assess and prioritise the impact of uncertain events on highway construction projects, and it provides researchers with a qualitative and quantitative methodology and a mathematical model for use in evaluating the effect of uncertain events on highway construction projects in South Africa. The SRA was used in assessing the impact of uncertain events on highway construction completion time, due to the fact that the model has a strong mathematical background and has been employed in assessing risk and uncertainty in the field of construction management. The study found the SRA model to be a reliable and statistically significant method for assessing uncertainty on construction projects. However, the accuracy of the estimated impact of some of the models is low. Therefore, to accurately estimate the impact of these events, the study recommends using a systematic fuzzy inference system, such as an adaptive neuro-fuzzy inference system (ANFIS).

The detailed analysis and estimated outputs from this research should be used as a platform and a benchmark for future studies in highway construction in South Africa. This platform should be utilised for estimating the duration of highway construction projects accurately, by assessing the uncertain events that impact on the completion time of each construction activity.

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