Spatial Analysis of Construction Accidents in Kampala, Uganda

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Abstract:
Construction work is one of the leading sources of occupational injuries and fatalities in Uganda. This paper set out to investigate the causes of accidents in Kampala, Uganda using spatial analysis tools of visualisation, Ordinary Least Squares (OLS) regression and spatial regression modelling. A cross-sectional survey consisting of a sample of 90 projects randomly selected from a population of 130 large size building projects commissioned by Kampala City Council in 2008 was undertaken. The collected data was supplemented by building records from Kampala City Council, safety statistics from the department of occupational safety and health, and accident investigation reports. Results presented in this paper show that the three most prevalent causes of accidents in Kampala are mechanical hazards (i.e. struck by machines, vehicles, hand tools, cutting edges etc.), being hit by falling objects and falls from height. Congestion, a phenomenon which arises when there is evidence of high building density amidst many fulltime workers on site, is discussed. Based on the results of this paper, the injury rate for Kampala is 4,248 per 100,000 workers and the fatality rate is 92 per 100,000 workers. All these findings are important to guide occupational safety policy formulation in Uganda.

Keywords: accidents, construction industry, regression modelling, spatial analysis.

1. Introduction

The construction industry is regarded as one of the major indicators of economic performance especially for developing countries (Ofori, 1990; Finkel, 1997). Periods of prosperity are usually associated with high levels of construction output. However, despite its clear economic benefits, the construction industry, globally, has a poor safety record (Rowlinson, 2004; Hinze, 2007). In Europe, the construction industry produces 30% of fatal industrial accidents, yet employs only 10% of the population (Peckitt et al., 2004). In the United States of America (USA), the incidence rate of accidents in the construction industry is reported to be twice that of industrial average. According to the USA National Safety Council (NSC), there are an estimated 2,200 deaths and 220,000 disabling injuries each year (Rowlinson, 2004). Construction fatalities account for 30-40% of industrial fatal accidents in Japan and 50% in Ireland (Peckitt et al., 2004). In the United Kingdom(UK), reported major injuries to employees in construction was 3,677 in 2005/6, compared to 3,768 in 2004/5 and 4,386 in 1999/2000 (HSE, 2007).

The difference in accident rates between developed and developing countries is remarkable (Hamalainen et al, 2006). While many construction businesses in developed countries have embraced a zero accident policy as their goal and implemented effective health and safety practices (Hinze and Wilson, 2000), construction businesses in developing countries are unable to even identify their hazards (Hamalainen et al, 2006). Proper accident recording and notification systems are non-existent in many developing countries (Hamalainen et al, 2006). In Sub-Saharan Africa, the fatality and injury rates in the construction industry are at 21 and 16,012 per 100,000 workers, respectively (CIDB, 2010). These records are markedly higher than the average fatality rate of 4.2 and injury rate of 3,240 per 100,000 workers in developed countries (CIDB, 2010). Comparatively, the accident record for Sub-Saharan Africa is similar to that of Asia which has fatality and injury rates of 21.5 and 16,434 per 100,000 workers, respectively (CIDB, 2010).

Similar to trends observed elsewhere amongst developing countries, Uganda has registered high accident rates in the recent past. Between 1996 and 1998 a total of 146 accidents were reported in the construction industry, 17 of which were fatal cases (Lubega et al., 2000). During the period 2001 to 2005, the annual averages were 54 cases on building sites, 103 cases on construction sites including buildings and 384 cases for all industries, construction inclusive (Alinaitwe et al., 2007). Overall, during the period 2001 to 2005, although the industry contribution of construction accidents was 27%, 4% lower than the accidents rate reported in the late 1990s, the number of incidences actually increased.

During the period 2006 to 2010, although a detailed study has not been undertaken in Uganda to establish the incidence rates, based on cases that have been reported by Irumba et al. (2010), it is evident that the construction industry in Uganda has continued to witness fatal accidents with a total of 49 fatalities reported in Kampala metropolitan area alone.

This paper investigated the causes of construction accidents in Kampala using spatial analysis tools. In particular, the paper employs tools on visualisation, Ordinary Least Squares (OLS) regression and spatial regression modelling. In order to achieve these objectives, the paper has been structured into six sections. Accordingly, section 2 discusses the theory on spatial autocorrelation and spatial regression modelling, section 3 highlights the hypotheses tested in the paper and methodology is presented in section 4. Results are presented and discussed in section 5 and finally, conclusions are made in section 6.

2. Spatial autocorrelation and spatial regression modelling

Spatial autocorrelation is a frequent phenomenon in real estate and construction data because observations (for example, prices of houses) from nearby locations are often related to each other than would be expected on a random basis (Dubin, 1998; Wilhelmsson, 2002). In this context, spatial autocorrelation refers to the correlation of a variable with itself in space (Haining, 2003). The presence of spatial autocorrelation in data can affect estimates made using the data and inferences made thereof especially for classical statistical tests of Analysis of Variance (ANOVA), correlation and regression (Kissling and Carl, 2008). Spatial autocorrelation, like temporal autocorrelation, violates the standard statistical techniques that assume independence among observations (Kissling and Carl, 2008). This is particularly the case in regression modelling. Therefore, treatment of spatial autocorrelation was of critical concern during regression modelling of construction accidents data in Kampala.

Let us start the discussion with the Ordinary Least Squares (OLS) regression model equation (1), given below.

$$Y = X\beta + \varepsilon \qquad (1)$$

Where Y is an n by 1 vector of observations on a dependent variable, X is an n by k matrix of observations on exogenous (explanatory) variables, with an associated k by 1 vector of regression coefficients, and ε is an n by 1 vector of random disturbance (error) term (Anselin, 2003). Although OLS is the approach widely used during regression analysis, for it to be accurate a number of assumptions have to be made. In particular, the assumptions about exogenous fixed independent variables, constant variance across the sample data, and no correlation between included independent variables and the error term are problematic in cross-section or pooled data sets (Wilhelmsson, 2002). Samples of real estate and construction data suffer omitted variable bias owing to the fact that all neighbourhood attributes are seldom included in the regression model (Wilhelmsson, 2002). If ignored, spatial autocorrelation can lead to unbiased but inefficient estimation of coefficients in OLS, as well as biased variance estimates (Conway et al., 2010).

In order to improve the quality of OLS results, Spatial Autoregressive (SAR) models are commonly used (Anselin, 2002; 2003). The use of SAR models improves the overall goodness of fit and the estimated spatial parameter is highly significant (Wilhelmsson, 2002). SAR models assume that the response at each location *i* is a function not only of the explanatory variable at *i*, but of the values of the response at the neighbouring locations *j* as well (Haining, 2003). In this case, the neighbourhood relationship is formally expressed by a matrix of spatial weights, W (Kissling and Carl, 2008).

In spatial modelling, two types of SAR models are distinguished: spatial lag model (SAR_{lag}) and spatial error model (SAR_{err}). Wilhelmsson (2002) gives a mixed spatial model equation as:

$$Y=\rho W_1 Y+X\beta+\mu$$
$$\mu=\lambda W_2\mu +\varepsilon \qquad (2)$$

Where the parameter ρ is the coefficient of the spatially lagged dependent variable and measures the spatial autocorrelation between observation *i* and *j*. The parameter λ is the coefficient in the spatial autoregressive structure for the disturbance term, ε. Here, ε is an n by 1 vector of normally distributed and independent error terms with zero mean and standard deviation, σ^2. OLS estimates of ρ and λ are biased and inconsistent, and therefore, they must be estimated by maximising a likelihood function (Wilhelmsson, 2002). W_1 andW_2 are the exogenously determined spatial weight matrices.

From equation (2) above, a spatial lag model (SAR_{lag}) means that λ=0 resulting into equation (3).

$$Y=\rho WY+X\beta+\varepsilon \qquad (3)$$

The spatial lag model assumes that the autoregressive process occurs only in the response variable i.e. there is inherent spatial autocorrelation (Kissling and Carl, 2008). Similarly, from equation (2), the spatial error model (SAR_{err}) equation is derived when ρ=0 resulting into equation (4).

$$Y= X\beta+\mu$$
$$\mu=\lambda W\mu +\varepsilon \qquad (4)$$

The spatial error model assumes that the autoregressive process is found only in the error term (Kissling and Carl, 2008). This is the most likely case if spatial autocorrelation is not fully explained by the included explanatory variables. Therefore, it is a typical case of induced spatial autocorrelation, for example, which can arise when an important spatially structured explanatory variable has not been taken into account (Kissling and Carl, 2008).

Finally, from equation (2), when $\rho=\lambda=0$, the mixed spatial model equation is reduced to the OLS model equation (1). Anselin (2002) observes that what is not always well understood in spatial regression modelling, is that different spatial models induce sometimes radically different spatial correlation patterns, which do not necessarily match the underlying theoretical interaction model. To that effect, it is always a good practice to compare results obtained using different spatial models before any conclusions are made.

3. Hypotheses

Accidents rarely just happen. They are usually as a result of failures of technology, failures of people or a combination of both (Priemus and Ale, 2010).The causes are seldom simple or singular; they are complex constellations of events, existing preconditions and of system properties (Priemus and Ale, 2010). The root causes of accidents in the construction industry are numerous. Toole (2002) summarises these causes under eight categories: lack of proper training in recognising and avoiding job hazards, deficient enforcement of safety standards, lack of safety equipment, unsafe methods of work and/or poor planning of project activities, unsafe site conditions, workers not using the provided safety equipment, poor attitude of workers towards safety, and isolated sudden deviation of a worker from prescribed behaviour. In summary, the root causes of accidents identified by Toole (2002) can be classified in two broad categories (1) causes of accidents due to faults by a worker and (2) causes of accidents due to faults by the employer (client or contractor).

In Uganda, previous research has shown that construction accidents that can be attributed to faults by the employer are more prevalent compared to those that can be attributed to faults by workers. For example, Lubega et al (2000) based on a survey conducted in five districts identified the major causes of accidents as inadequate supervision of projects, use of incompetent personnel and use of inappropriate construction techniques. Similarly, following a country wide survey, Alinaitwe et al. (2007) identified the five major causes of accidents during the period 2001 to 2005 as collapse of parts of buildings under construction, falls from height, machines, being hit by vehicles and cuts. Many falls are due to poor scaffolding that is employed on building sites in Uganda and the many cases of accidents from machines and vehicles are due to lack of experience and training by the operators (Alinaitwe et al., 2007).

In this paper, three hypotheses are tested. These hypotheses largely relate to causes of accidents due to faults by the employer and address some of the concerns cited above. The hypotheses are stated below:

Hypothesis one: occurrence of accidents on construction sites is dependent on the level of congestion on site. In this context, congestion is measured in terms of building density (defined as the ratio of gross floor area to plot acreage) and size of workforce.

Hypothesis two: regular servicing and maintenance of construction equipment reduces the rate of accidents occurrence on construction sites.

Hypothesis three: provision of an efficient scaffolding and ladder system reduces the rate of accidents occurrence on construction sites.

4. Methodology

4.1 Research design

The research design adopted in this paper is a cross-sectional survey design. A cross-sectional design consists of a sample of data taken at a given point in time (Wooldridge, 2009). Sometimes the data on all units in the sample do not correspond to precisely the same point in time, for example, data may be collected during different months of the year. In a pure cross-sectional analysis, minor timing differences in collecting the data can be ignored (Wooldridge, 2009). Cross sectional data exhibits validity comparable to other data types, in particular, longitudinal data (Rindfleisch et al., 2008). The method addresses validity concerns related to common method variance bias and causal inferences (Rindfleisch et al., 2008).

Cross-sectional data design is widely used in construction industry research. For example, Chau and Walker (1988) used cross-sectional data in a study on measurement of total factor productivity of the Hong Kong construction industry, Dedobbeleer and Beland (1991), and Pousette et al. (2008) used a cross sectional survey design to measure safety climate on construction sites in Baltimore MD, USA and in Goteborg, Sweden respectively. Many similar studies can be cited in construction literature.

4.2 Framing Kampala as a case-study area

Kampala is the capital city of Uganda. It covers an area of 839km^2 (Giddings, 2009), and had a resident population of 1,600,000 by 2008 or 5.8% of the national population (UBOS, 2009).The choice of Kampala as a case-study area was informed by the fact that out of the total number of construction accidents reported in Uganda, over 60% of the cases are registered in Kampala alone (OSHD, 2009).This qualifies the region as a hot spot for accident investigations. Kampala is a regional hub of construction activity. In terms of value addition to economic activities, during the year 2010, construction contributed 3,161 billion Uganda shillings out of the Total GDP at market prices of 20,771 billion Uganda shillings or 15.2% up from 14.5% in 2009 (Budget Report, 2011). This was markedly the sector with the highest contribution to GDP.

4.3 Data

In this paper, a cross section survey consisting of a sample of 90 projects randomly selected from a population of 130 large size building projects commissioned by Kampala City Council in 2008 was conducted. The response rate was 68% or a total of 61 construction sites. The selected projects were multi-storeyed structures with a minimum floor area space of 1000 m^2, a minimum building cost of 200 million Uganda shillings and employed 20 up to 350 fulltime workers on site. Data was collected on project characteristics (i.e. type, size, cost, acreage, duration and work force), accident statistics (major injuries and fatalities), causes of accidents and on safety protection facilities provided on site. Minor injuries (i.e. first aid cases) were not included in analysis because most site managers do not keep a formal register of these statistics. The inclusion of such data had potential to introduce bias in the study. The causes of accidents investigated included collapse of building walls, collapse of excavation works, falls from height, being hit by falling objects, mechanical hazards, workers affected by chemicals and other substances, cases of contact with electricity and electric discharge, and burns from gas flames and hot objects. In addition, usage of the necessary safety protection systems provided for by relevant legislation was investigated. In addition to project characteristics and accident statistics, data on spatial positions (i.e. x and y coordinates) of construction sites was collected.

As measure to improve data quality, the survey data was supplemented by records from the building department in Kampala City Council as well as those of the Occupational Safety and Health department in the Ministry of Gender, Labour and Social Development. Accident investigation reports prepared by Ministry of Works, Transport & Communication, Uganda Institute of Professional Engineers, and the Occupational Safety and Health department were also reviewed.

5. Results

The results presented in this paper were obtained using three main software. Compilation of the data set and descriptive statistics was done in STATA 11 statistical package, mapping of accidents was done in ArcMap 10 software and spatial regression modelling was done in GeoDATM 0.9.5-i spatial analysis software. Accordingly, the results obtained are explained in sections 5.1to 5.3 below.

5.1 Descriptive Statistics

The cross sectional survey elicited attribute data from 61 construction sites in Kampala. This data has two distinct categories: projects characteristics (independent variables) and accident statistics (dependent variables). The data is summarised in Table 1.

From the results presented in Table 1, it is evident that the three most prevalent causes of accidents in Kampala are mechanical hazards (i.e. struck by machines, vehicles, hand tools, cutting edges etc.), being hit by falling objects and falls from height with prevalence rates of 4.60, 3.05 and 2.00 cases per building site, respectively. The high accident rates due to mechanical hazards can be explained by failure of most building contractors to regularly service and maintain construction equipment, and inadequate training of workers in equipment use. It can also be a result of congestion on building sites, characteristic of urban areas, which increases the risk of collision with vehicles and other mobile construction equipment. Accidents resulting from being hit by falling objects can be explained by poor methods of work on site, especially defective formwork systems. As highlighted earlier (see section 4), falls from height in Uganda are largely a result of poor scaffolding systems. In relation to findings by Alinaitwe et al. (2007), mechanical hazards (which they separately classify as machines, being hit by vehicles and cuts) and falls from height are still leading causes of accidents on building sites in Uganda.
The results presented in Table 1 also show that an average work week on building sites in Kampala has 59.94 hours. This is markedly higher than the International Labour Organisation (ILO) standards (to which Uganda subscribes) which prescribe a work week of 48hours. The ILO standards on working hours are spelt out in the ILO convention No.1 of 1919, ILO convention No. 30 of 1930 and were re-affirmed in the 93rd ILO conference on working hours held on 13th June 2005 in Geneva. The above workweek statistics translate into an overtime effect (defined as a ratio of actual work week to the standard workweek) of 1.25. Hypothetically, working overtime

increases the probability of workers to make mistakes which can lead to occurrence of accidents on building sites.

Table 1: Descriptive Statistics

Variable	Unit	Average	Std. Dev	Min	Max
Gross Floor Area	m^2	6,439.635	10,189.73	1000	60,979.11
Height of building	m	18.88	10.17	6.6	52
Number of storeys	m	5.45	2.81	2	15
Building cost	million UGX	7,550.79	21,205.61	215	144,000
Plot size	m^2	3136.44	3776.86	470	20000
Project duration	months	18.85	13.18	4	72
Work week	hours	59.94	21.54	40	168
Workforce	no.	64.16	58.39	20	353
Collapse of walls	no.	0.17	0.62	0	3
Collapse of excav. Works	no.	0.45	1.98	0	11
Falls from height	no.	2.00	5.11	0	28
Hit by falling objects	no.	3.05	6.10	0	33
Mechanical hazards	no.	4.60	10.57	0	55
Affected by chemicals	no.	0.13	0.75	0	5
Contacts with electricity	no.	0.20	0.69	0	4
Burns	no.	0.21	0.90	0	6
Injuries	no.	2.72	3.51	0	20
Fatalities	no.	0.18	1.01	0	7
Total number of accidents	no:	2.90	3.54	1	20
Provision of personal protection equip.	binary	0.72	0.45	0	1
Provision of signs & signals on site.	binary	0.39	0.49	0	1
Provision of first aid facilities.	binary	0.78	0.41	0	1
Conducting safety training & meetings	binary	0.41	0.50	0	1
Provision of fall protection equip.	binary	0.20	0.40	0	1
Provision of walk &drive ways	binary	0.49	0.50	0	1
Provision of lighting facilities	binary	0.49	0.50	0	1
Employing experienced workforce	binary	0.82	0.38	0	1
Proper handling of electrical equip.	binary	0.45	0.50	0	1
Provision of fire prevention facilities	binary	0.13	0.35	0	1
Provision of guard railing systems	binary	0.51	0.50	0	1
Regular maintain. of constr. equip.	binary	0.47	0.50	0	1
Provision of cranes & lifting equip.	binary	0.57	0.50	0	1
Provision of mobile work platforms	binary	0.09	0.30	0	1
Provision of scaffolding & ladders	binary	0.92	0.27	0	1
Regular maintain. of hand & power tools	binary	0.71	0.46	0	1
Proper handling of hazardous material	binary	0.39	0.49	0	1
Materials lab. Testing	binary	0.49	0.50	0	1
Proper handling of chemicals	binary	0.24	0.42	0	1
Hoarding	binary	0.92	0.27	0	1

Building density	ratio	2.42	2.15	0.13	9.58
Overtime effect	ratio	1.25	0.45	0.83	3.50
Distance to CBD	km	3.09	1.97	0.09	6.58

5.2 Mapping of construction accidents in Kampala

A construction safety map of Kampala was developed in ArcMap 10. The objective of mapping was to use visualisation as a tool for spatial analysis of construction accidents. This safety map (Figure 1) contains the following main feature classes: construction accident sites, commercial centres, transport infrastructure (air strips, roads, and railway lines), water bodies (lakes and rivers), swamps, built-up areas and administrative boundaries.

From the safety map, it is evident that Kampala central has a high level of construction activity compared to other administrative divisions. The majority of construction sites surveyed, on average, are located 3km from the city centre with the closest and most distant being 0.09km and 6.58km from the city centre, respectively. Through querying the attribute data of the accident sites feature class, it was observed that accidents are more prevalent on commercial buildings compared to industrial buildings, institutional buildings and to residential apartments. Indeed, most commercial buildings are high rise blocks over 18m high which makes them susceptible to accidents due to fall from height especially in an environment where scaffolding systems are poor. Statistics showing the distribution of accidents according to administrative divisions are displayed in Table 2 below.

Table 2: Distribution of accidents according to administrative divisions

Division name	No. of construction sites	No. of accidents	Rate (no. of cases per construction site)
Central	25	92	3.68
Kawempe	07	08	1.14
Lubaga	07	15	2.14
Makindye	11	17	1.55
Nakawa	11	33	3.00
Totals/average rate	**61**	**165**	**2.70**

The results presented in Table 2, above, show that central division has the highest accident rate of 3.68 cases per construction site followed by Nakawa division at 3.00 cases per construction site. These high accident rates can be explained by the high level of building activity prevalent in these divisions.

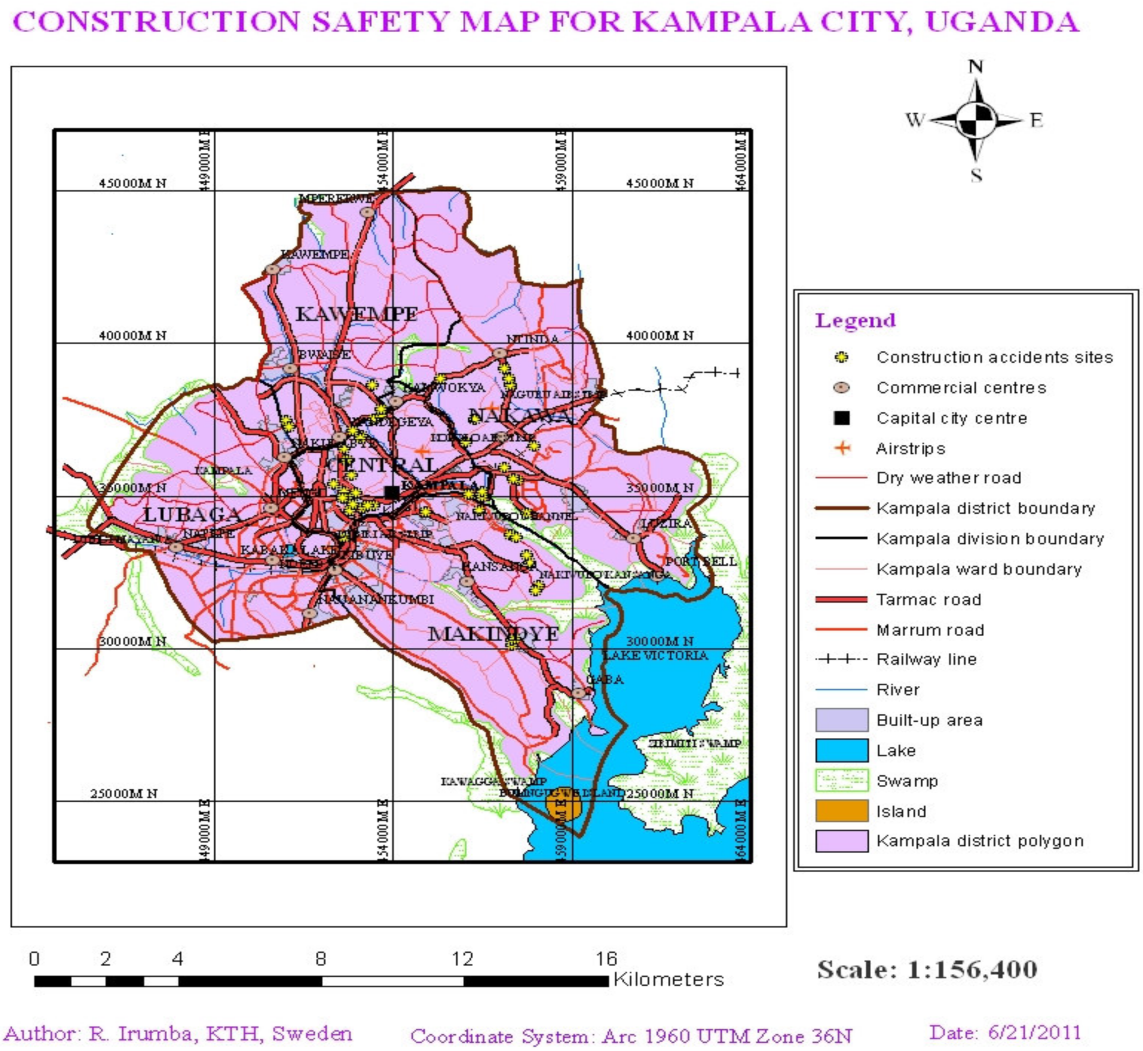

Figure 1: Construction safety map of Kampala

Overall, based on the results of this paper, the incidence rate due to injury (i.e. total number of injuries divided by the total number of workers, multiplied by 100,000) for Kampala is 4,248 per 100,000 workers and the fatality rate (i.e. total number of fatalities divided by total number of workers, multiplied by 100,000) is 92 per 100,000 workers.

5.3 Regression modelling results

Regression modelling was undertaken based on the OLS regression equation (5) given below.

tot_accid = β_o+ $\beta_1$build_density + $\beta_2$tot_workers+ $\beta_3$mech_insp+$\beta_4$scaf_lad+ε (5)

Where, tot_accid is the total number of accidents, β_o is a vector of constants, β_1, β_2,β_3, β_4 are coefficients of the independent variables building density (build_density), total number of workers (tot_workers), regular inspection and maintenance of construction equipment (mech_insp), and provision of an efficient scaffolding & ladder system (scaf_lad), respectively and ε is the disturbance term (i.e. residuals).

A summary of regression modelling results is given in Table 3. These statistics relate to OLS regression, spatial lag and spatial error regression modelling.

Table 3: Regression modelling results

Variable	**OLS regression**		**Spatial lag model**		**Spatial error model**	
	Coeff.	*t-stat.*	*Coeff.*	*z-stat.*	*Coeff.*	*z-stat.*
Constant	5.0853	2.95	5.0121	2.98	5.1136	3.14
Build_density	0.0354	0.16	0.0315	0.15	0.0468	0.21
tot_workers	0.0225	2.72	0.0227	2.90	0.0234	3.04
Mech_insp	-0.0259	-0.03	-0.0659	-0.07	-0.1898	-0.21
Scaf_lad	-4.0172	-2.34	-4.0304	-2.47	-4.0386	-2.52
W_tot_ACD			0.0389	0.21		
Lambda					0.1069	0.57
R- squared	0.2178		0.2213		0.2333	
Adj. R-squared	0.1498					
Log likelihood	-130.146		-130.057		-129.774	
Akaike Information Criteria (AIC)	270.292		272.113		269.547	
Moran's I stat.	0.1043					
Likelihood ratio test (value/ probability)			0.1785 /0.6726		0.7445/0.3882	
Lagrange multiplier (lag) (value/ probability)	0.3653/0.5456					
Lagrange multiplier (error) (value/ probability)	1.1104 /0.2920					

From the regression results presented in Table 3 above, the Moran's I statistic value of 0.1043 is less than the normal standardised z-value of 1.96 at 5% significance level. Moran's I statistic is used to determine the extent of the linear association between the values on a given location with values of the same variable in neighbouring locations (Anselin, 2005). Moran's I for row standardised weights is computed using equation (6) below:

$$I = e'We/e'e \qquad (6)$$

Where e is an n by 1 vector of regression residuals from OLS estimation of equation (5). From the above results, the Moran's I statistic is less than the critical value suggesting that the null hypothesis of no spatial correlation is accepted. Similarly, the Lagrange multiplier values for spatial lag and spatial error models at 0.3653 and 1.1104, respectively, are both less than the critical value of 1.96 at 5% significance level. Lagrange Multiplier (LM) statistics measure the correlation in residuals of a regression model (Wilhelmsson, 2002). The results of LM statistics confirm the earlier position that there is no spatial autocorrelation between the independent variables and the error term (i.e. residuals) in equation (5). Therefore, OLS results can be relied on as good estimates of the model.

Let us now address ourselves to the hypotheses being tested in this paper.
Hypothesis one: occurrence of accidents on construction sites is dependent on the level of congestion on site.

In equation (5), congestion on construction sites is expressed in terms of building density and the number of workers on site. High building density is a clear manifestation that a large part of land is built up. As a consequence, there is limited room for workers and mobile construction equipment to manoeuvre on site. These events increase the risk of registering accidents due to collisions between 'people and machines' and/or between 'machines and machines'. The risk factor of collision is high on sites with many workers and low on sites with few workers.

Turning to results in Table 3, the independent variables building density and total number of workers both have positive coefficients, suggesting a positive relationship between them and the dependent variable, total number of accidents. This confirms the hypothesis that accidents are dependent on the level of congestion on construction sites.

Hypothesis two: regular servicing and maintenance of construction equipment reduces the rate of accidents occurrence on construction sites.

As discussed earlier in section 5.1, mechanical hazards are the leading cause of accidents on construction sites in Kampala. Hypothesis two seeks to mitigate this type of accident. From the results of regression analysis presented in Table 3, the variable on regular servicing and maintenance of equipment has a negative coefficient. This suggests that regular servicing and maintenance of equipment reduces the risk of accident occurrence. However, given that the corresponding t and z-statistics at -0.03, -0.07 and -0.21 for OLS, spatial lag and spatial error models, respectively, are both less than the critical value of 1.96 at 5% significance level suggests that regular servicing and maintenance of construction equipment does not significantly reduce the number of accidents registered on construction sites. Therefore, hypothesis two as stated above is rejected.

Hypothesis three: provision of an efficient scaffolding and ladder system reduces the rate of accidents occurrence on construction sites.
Results of this paper (see section 5.1 for details) have shown that falls from height is the third most leading cause of accidents in Kampala. From Table 3 above, the coefficient (β_4) is negative suggesting that the provision of an efficient scaffolding & ladder system can reduce the number of accidents registered on construction sites. The corresponding t and z statistics at -2.52, -2.47 and -2.34 for OLS, spatial lag and spatial error models, respectively, are both higher than the critical value of 1.96 at 5% significance level. This confirms hypothesis three as stated above. Judging from the magnitude of the coefficient (i.e.-4.0172), this variable has the greatest potential to reduce occurrence of accidents on construction sites.

In summary, the results of regression modelling have confirmed hypothesises on congestion of building sites and on provision of efficient scaffolding and ladder system but rejected the hypothesis on regular servicing and maintenance of construction equipment.

6. Conclusions

This paper set out to investigate the causes of accidents on construction sites in Kampala using spatial analysis tools. The results of this paper have shown that the three most prevalent causes of accidents in Kampala are mechanical hazards (i.e. struck by machines, vehicles, hand tools, cutting edges etc.), being hit by falling objects and falls from height with prevalence rates of 4.60, 3.05 and 2.00 cases per building site, respectively. Mechanical hazards are a result of poor maintenance of construction equipment and inadequate training of workers in equipment use. Accidents resulting from being hit by falling objects result from poor methods of work on site, especially defective formwork systems. Notably, as has been the case in the recent past, falls from height (in Uganda) are largely a result of poor scaffolding systems. Congestion on construction sites, a concept not widely documented in construction safety literature, has been discussed in this paper. Congestion arises when there is evidence of high building density amidst many fulltime workers on site. Congestion is more prevalent in urban areas. It was noted that congestion increases the risk of registering accidents due to collisions between 'people and machines' and/or between 'machines and machines'. From the results of this paper, it was deduced that the incidence rate due to injury for Kampala is 4,248 per 100,000 workers and the fatality rate is 92 per 100,000 workers. All these findings are important to guide occupational safety policy formulation in Uganda.

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