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The Effect of Season on Construction Accidents in Saudi Arabia

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THE EFFECT OF SEASON ON CONSTRUCTION ACCIDENTS IN SAUDI ARABIA

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تأثير فصول السنة على حوادث التشييد في المملكة العربية السعودية

ملخص

يتعرض عمال الإنشاءات عند العمل في مواقع التشييد إلى ظروف قاسية لوقت طويل عند تأدية أعمالهم اليومية خلال فصول السنة المختلفة. لقد ناقشت بعض الدراسات تأثير التوقيت الموسمي للإصابات المرتبطة بالعمل وخلصت إلى أن كثير من الإصابات تحدث خلال أشهر الصيف. كما خلصت دراسات أخرى إلى أنه من الأرجح أن تحدث الإصابات خلال مواسم الأمطار. تم الحصول على بيانات حوادث التشييد لسنة 2004م إلى 2011م من المؤسسة العامة للتأمينات الاجتماعية بالمملكة العربية السعودية. أظهر تحليل أنوفا ANOVA ذو الاتجاهين أنه لا يوجد هناك فروق ذو دلالة إحصائية بين السنوات من حيث عدد الحوادث، ولكن كانت هناك فروق ذو دلالة إحصائية عالية بين فصول السنة. أظهر اختبار شيف (Scheffe) أن أكثر الحوادث قد حصلت في فصل الربيع يليه فصل الصيف؛ وكان فصل الشتاء أقل من حيث عدد الحوادث يليه فصل الخريف. أظهر نموذج الانحدار الخطي بمتغيرات المؤشر (Regression with Indicator Variables) أن العلاقة بين فصل الربيع والفصول الأخرى كانت ذو دلالة إحصائية عالية. بشكل عام، كانت الحوادث في فصلي الربيع والصيف أعلى منها في فصلي الخريف والشتاء وبدلالة إحصائية عالية. وبناء على ذلك، فإن التفكير في لوائح السلامة بمواقع البناء، والإعداد، وعمل البرامج المناسبة، وفحص المعدات بشكل دوري يعتبر أكبر خط دفاع ضد وقوع الحوادث وخاصة في فصلي الربيع والصيف.

Abstract

Construction workers are exposed to extreme conditions over a large portion of the work day during the different seasons of the year when working on construction sites. Some studies have discussed the effect of seasonal timing of work-related injuries and concluded that more injuries occur during the summer months [1]. Other studies concluded that accidents are more likely to occur during rainy seasons [2]. Construction accidents data from 2004 to 2011 were obtained from the General Organization for Social Insurance (GOSI). A two way ANOVA analysis showed that there was no significant difference among the years in terms of number of accidents, but there was a significant difference among seasons. Scheffe testing showed that spring had the highest number of accidents followed by summer; and winter had the lowest number of accidents followed by fall. The regression model with indicator variables showed that the relationship of spring to other seasons were significant. In general, spring and summer seasons had significantly higher accidents than fall and winter. Therefore, thinking about safety regulations at construction sites, preparation, having the right programs, and timely equipment checking is the biggest defense against accident occurrence especially in spring and summer.

1. INTRODUCTION

The Construction industry is one of the largest global industries. It generates 12% of the world's gross domestic product (GDP) and is expected to grow rapidly as populations in China, Southern Asia, and the U.S. continue to expand [3]. It is one of the most hazardous industries. It has the highest casualty rate compared to other industries. Statistics confirm that the probability of accidents resulting in death is five times the average of accidents in other industries. Every year, many

people fall victim to injury, harm and even death caused by accidents on construction sites, [4]. Construction workers are exposed to numerous uncertainties, health and safety hazards on construction sites [5], [6]. Weather conditions such as hot and cold temperatures, strong winds, lightning, heavy rain, fog, and others cannot be controlled and may play a significant role in increasing the chance of accidents on construction sites. Construction workers are exposed to extreme conditions over a large portion of the work day. They work indoor and outdoor on construction projects during the different seasons of the year e.g., site preparation, construction or demolition of buildings and infrastructure, and building decoration and finishing [7]. Exposure to extreme weather conditions over time causes significant health risk, which impedes work performance, increases risks of accident, disability, and even fatality. Thereby, it increases construction cost, project duration and damage to the company's reputation. The majority of work-related injuries in Saudi Arabia occur in the building and construction sector in which 64% of accidents occur in this sector (GOSI), 2018).

Several studies have discussed the causes of accidents on construction sites. Others have investigated the frequency and severity of factors contributing to construction accidents [8], [9]. However, few studies have discussed the effect of season on accidents on construction sites. Some studies have discussed the effect of seasonal timing of work-related injuries and concluded that more injuries occur during the summer months than at other times of the year [1]. Others analyzed the Pattern of Seasonal Variation in construction accidents, and found that during the summer season, the risk of fall accidents among workers of age 21-40 and 41-60 is very high, and the increased risk of fall-related incidents due to unpredictable wet weather conditions is more likely to take place during the winter season [10]. Other studies concluded that the rainy season is the inevitable problem in the construction process and that accidents are more likely to occur in this rainy season [2]. According to Occupational Safety and Health Administration (OSHA), accidents know no season. They listed the top four causes of construction worker fatalities; which are falls, electrocutions, being struck by an object, and being caught in or between objects.

The different conclusions of the effect of season on accidents on construction sites, and the lack of studies about this issue in Saudi Arabia calls for the need to investigate it. This will help to improve regulations and laws in this matter, and avoid the occurrence of these accidents on construction sites during any season of the year. As a result, this will save lives, reduce construction cost, project duration and improve work quality.

2. RESEARCH OBJECTIVES

The main objective of this research is to investigate the relationship between the seasons and the rate of accidents on construction sites in Saudi Arabia. The minor objectives that will achieve the main objective are as follows:

- Determine the relationship between seasons and rate of accidents on construction sites in Saudi Arabia.
- Examine the nature of the relationship between seasons of the year and the rate of accidents.

3. LITERATURE REVIEW

Construction projects are highly subject to different weather and climate conditions such as thunderstorms, showers, tornados, blizzards, windstorms, wildfires, hurricanes, etc. These weather and climate conditions may lead to delay, disrupt, or stop the project. The term "construction season" itself denotes the importance of weather on construction activities [11]. In practice, construction planning, cost estimation, and management are strongly focused on continuous feedback and improvement where actual experience on last year's project becomes the template for next year's projects [11]. Researchers have studied work-related injuries for many reasons. Some were interested in seasonal patterns of worker productivity as they relate to economic activity [12]. Others like Forston (2004) [13], Barnes and Wagner (2009) [14] were interested in direct physiological effects associated with time of work or changing temperature or light. Others were looking at seasonal variation in injuries to gauge the possible importance of a particular type of misreporting [1].

There are several studies that have discussed the factors and causes in addition to severity of accidents on construction sites. Some have related several factors including weather and season changes to accidents and to labour productivity. The work of (Mohammadfam I, et al. 2015) [15] have stated that the occurrence and severity of construction accidents were due to the combination of failures in a collection of different contributing factors including accident time and place. The investigation of seasonal work indicated that most accidents occur in the first two seasons of the year, spring and summer. Rahmani et al (2013) [7] looked at an eight-year period of accidents among workers in electricity distribution companies in Iran. Their results indicated that the maximum and minimum number of work accidents happened in summer and autumn, respectively. They concluded that the growth of economic activities especially in the electricity sector in summer and the recession of them in autumn seems to explain the high rate of

accidents in summer. The high rate of accidents in summer may be due to the warm weather in Alborz province and west of Tehran, or insufficient professional skills and experience in seasonal workers including high school and university students. The findings of Rahmani et al (2013) [7] is consistent with the study of Hlvani et al.(2012) [16] on occupational accidents among construction industry workers in Yazd city, and the study of Faghih N et al. (2012) [17] on the analysis of work-related accidents in Fars Province in Iran. The study of Wood, L. (2017) [18] examined the socio-economic and physical determinants of workplace accidents and injuries, and whether the relationships between these risk-factors and accident rates vary geographically and seasonally. She concluded that the relationships between these risk-factors and accident rates vary geographically, with risk-factors appearing to have a stronger relationship with workplace accidents in particular seasons compared to others [18].

In winter months, daylight hours are shorter than those in summer and evenings become darker much earlier than the nights in summer. The work of Arditi et al. (2007) [19] found that night time construction work is five times more hazardous than daytime. Construction workers need clear visibility since their work is labour intensive and a light mistake could result in a major injury or even fatality. In general, there might be sufficient light during the daytime to carry out work, however during the night time, levels of light are reduced [20]. The work of Folkard and Tucker (2003) [21], and Mustard et al. (2013) [22] stated that there is a higher risk of work-related injury and illness in the evening, night and early morning, with safety declining over successive nights and longer hours of work. Generally, these work-related injuries and illness are thought to be due to two key points: workers suffering from poor visibility due to lack of lighting and workers being tired and sleepy during working hours [18].

Heat and cold in summer and winter seasons are believed to be associated with a higher risk of occupational injury. According to a study conducted by Martínez, E. et al., (2018) [23]. Exposure to moderate to extreme temperatures may have played a role in over half a million of the workplace injuries that occurred in Spain. Extremes of cold and heat increased the risk of injury by 4% and 9%, respectively. The study analyzed data on nearly 16 million occupational injuries that occurred in Spain over a 20-year period between 1994 and 2013, and concluded that extreme ambient temperatures increased the risk of occupational injuries, with substantial estimated health and economic costs [23]. Gasparrini et al (2015) [24] have conducted a study in 13 countries to investigate the effect of temperatures on mortality and morbidity, and estimated that 7.29% and 0.42% of total mortality can be attributed to cold and hot temperatures respectively. Some studies reported that extreme ambient heat has important losses in work capacity, productivity, and costs that amount to 0.1% and 0.5%. of GDP [25], [26], [27], [28]. Heat strain may decrease the performance and productivity of workers. The work of (Kjelstrom et al., 2016) [25] concluded that exposure to high temperatures can lead to physiological and psychological changes associated with heat strain, which in turn can decrease workers' performance and lead to impaired concentration, increased distractibility, and fatigue [25]. Working in cold weather, On the other hand may decrease workers' performance and dexterity. The work of (Schulte and Chun, 2009) [6], (Mäkinen and Hassi, 2009) [29], (Rodahl, 2003) [30] confirms that factors related to working in cold environments, such as thermal discomfort, hypothermia, or reduced mobility while wearing protective clothing are associated with decreased dexterity and performance among workers, which can also trigger occupational injuries.

The different conclusions of previous studies regarding the effect of seasons on occupational injuries calls for the need to investigate this issue in Saudi Arabia. This would help shed the light on this issue and it would help avoid the occurrence of these accidents on construction sites in any season by identifying the nature of the relationship between season and accidents on construction sites to construction professionals. This would be an impetus of improvement in construction law and regulation.

4. SEASONS IN SAUDI ARABIA

In most countries, the year is commonly divided into four seasons: spring, summer, fall or autumn, and winter. Each season lasts three months, and the beginning of each season marks the end of the last. There are two commonly used methods to define the beginning and end of seasons: the astronomical definition and the meteorological definition. The astronomical definition uses the dates of equinoxes and solstices to mark the beginning and end of the seasons. spring begins on the spring equinox; summer begins on the summer solstice; fall (autumn) begins on the fall equinox; and winter begins on the winter solstice. Since the timings of the equinoxes and solstices change each year, the length of astronomical seasons within a year and between years changes as well. The meteorological definition is adopted by many countries including Saudi Arabia, uses the first day of the month that includes the equinoxes and solstices as the beginning of the season. Therefore, in the Northern Hemisphere, where Saudi Arabia is located, spring runs from March 1 to May 31; summer runs from June 1 to August 31; fall (autumn) runs from September 1 to November 30; and winter runs from

December1 to February 28 (February 29 in a leap year). The meteorological seasons in the Southern Hemisphere are opposite to those in the Northern Hemisphere. Thereby, spring starts September 1 and ends November 30; summer starts December 1 and ends February 28 (February 29 in a Leap Year); fall (autumn) starts March 1 and ends May 31; and winter starts June 1 and ends August 31.

5. METHODOLOGY

5.1 DATA COLLECTION

Historical data of accidents on construction sites were obtained from the General Organization for Social Insurance (GOSI). GOSI is a Saudi government agency that provides insurance for construction contractors who are working on projects in the public or private sector in Saudi Arabia. They also provide payment for retirement and worker compensation. Construction accidents data between 1425 to 1432 Hijri (2004 to 2011) were used in the analysis since they have similar format published by GOSI.

5.2 DATA ANALYSIS

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS). Data analysis consists of two parts: descriptive and quantitative analysis. One way ANOVA was performed to compare the season levels in terms of number of injuries, and a two way ANOVA was performed to compare the difference among the years. In addition, a regression model with indicator variables was used to compare the four season groups, spring, summer, fall, and winter in terms of slopes and intercepts of the number of accidents. Spring season was used as the base group for comparison in the regression model because it has the highest number of accidents. The confidence interval used in the analyses was taken as 95%, and the significance level was taken as $p < 0.05$.

6. DISCUSSION AND RESULTS

6.1 DESCRIPTIVE ANALYSIS

NUMBER OF MEMBERS OF GOSI PER YEAR

There was an increase in the number of members at the General Organization for Social Insurance (GOSI) every year between the years 1425H (2004) to 1432H (2011). The number of members in 1425H (2004) was (833,098) and it increased to (916,505) in 1426H (2005), (1,055,496) in 1427H (2006), (1,248,774) in 1428H (2007), (1,410,517) in 1429H (2008), (1,599,903) in 1430H (2009), (1,825,862) in 1431H (2010), and (2,174,962) in 1432H (2011), with percentages of increase of 10%, 15%, 18%, 13%, 13%, 14%, and 19% respectively. Table (1), and figures (1), (2) show the number and percentage of increase of members every year.

Year	Number of Members	Percentage of Increase
1425 (2004)	833,098	-
1426 (2005)	916,505	10%
1427 (2006)	1,055,496	15%
1428 (2007)	1,248,774	18%
1429 (2008)	1,410,517	13%
1430 (2009)	1,599,903	13%
1431 (2010)	1,825,862	14%
1432 (2011)	2,174,962	19%

Table (1) Number of Members of GOSI and Percentage of increase per Year

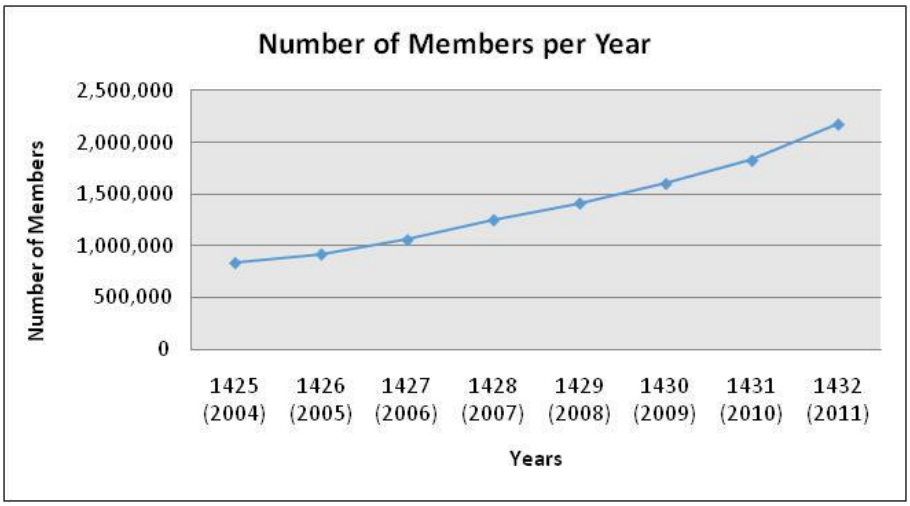

Figure (1) Number of Members of GOSI per Year

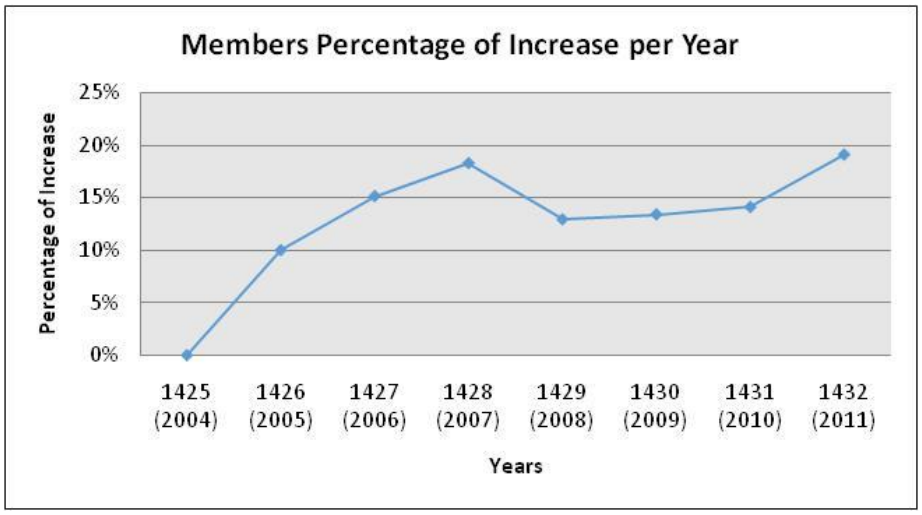

Figure (2) Members of GOSI Percentage of Increase per Year

NUMBER OF ACCIDENTS PER YEAR

There was an increase in the number of accidents in the first year of 1426H (2005) compared to the year 1425H (2004) in terms of number of accidents as (42,326) compared to (39,299) with an 8% increase. Then it started to decrease 12% in 1427 (2006) and slightly increased 4% and 14% in 1428H (2007) and 1429H (2008) respectively. After that, the number of accidents started to decrease 3%, 13%, and 3% in 1430H (2009), 1431H (2010), and 1432H (2011) respectively. Table (2) and figure (3) show the number of accidents and the percentage of increase per year.

Year	No. Of Accidents	Percentage of Increase
1425 (2004)	39,299	-
1426 (2005)	42,326	8%
1427 (2006)	37,427	-12%

1428 (2007)	38,929	4%
1429 (2008)	44,430	14%
1430 (2009)	43,308	-3%
1431 (2010)	37,527	-13%
1432 (2011)	36,367	-3%

Table (2) Number of Accidents and Percentage of increase per Year

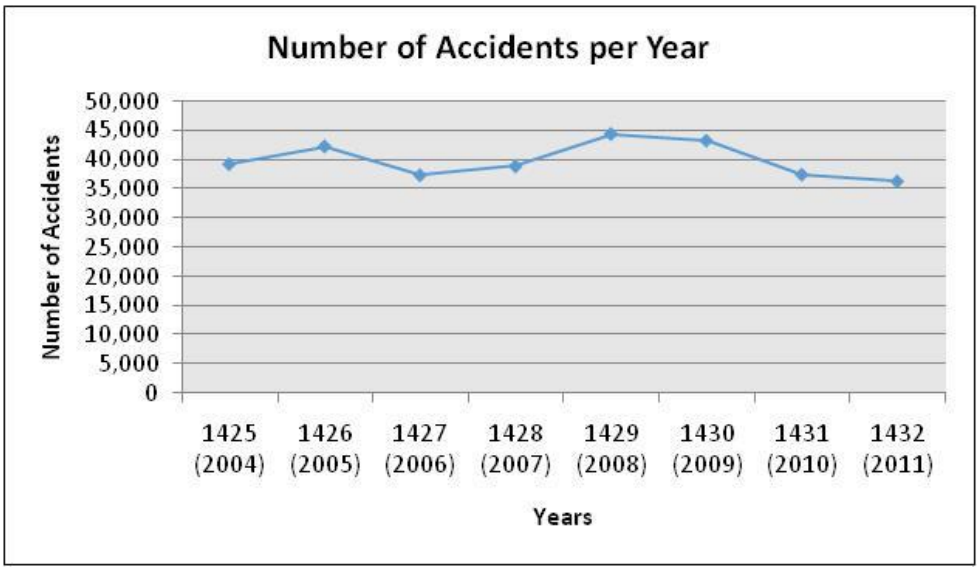

Figure (3) Number of Accidents per Year

AVERAGE NUMBER OF ACCIDENTS PER HIJRI MONTH

The average number of accidents increased in general at the first five months of the year. Then it started to go down to reach its lowest average at the end of the year. Notice that there is a significant drop in terms of accident rates in the 9th and 12th month of the Hijri year. These months have a significant number of holidays and shortened working hours.

Table (3) and figure (4) show the mean value of accidents in each Hijri month of the year.

Month	Mean Value	Percentage of Increase
1	3298.56	-
2	3633.44	10.15%
3	3676.33	1.18%
4	3592.56	-2.28%
5	3858.56	7.40%

6	3736.56	-3.16%
7	3288.89	-11.98%
8	3126.67	-4.93%
9	2164.44	-30.77%
10	2441.56	12.80%
11	2564.78	5.05%
12	1636.56	-36.19%

Table (3) Average Number of Accidents and Percentage of Increase per Hijri Month

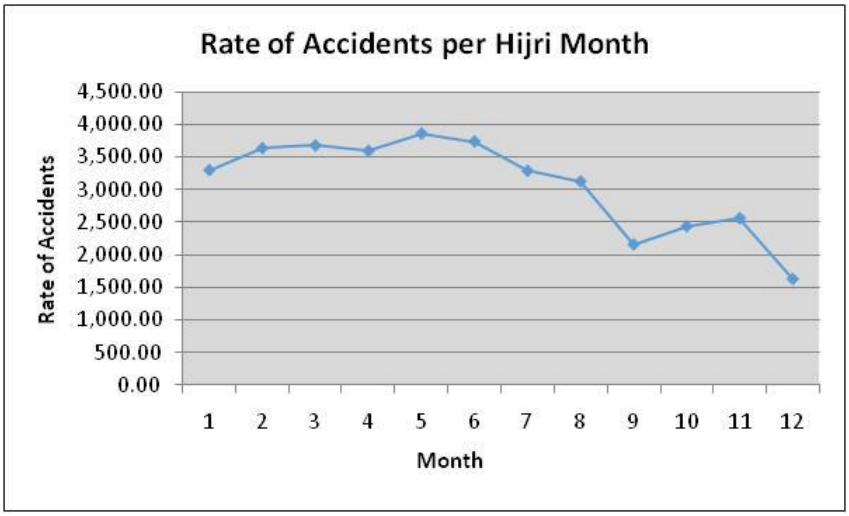

Figure (4) Average Number of Accidents per Hijri Month

AVERAGE NUMBER OF ACCIDENTS PER SEASON

The mean value of accidents in spring, summer, fall, and winter were (3903.96), (3697.42), (2837.25), and (2803.58) respectively. The standard deviations were (561.92), (816.62), (647.26), and (890.61) respectively. Spring and summer had the highest average number of accidents and they were close to each other in term of mean values (3903.96) and (3697.42) respectively. Winter and fall had the lowest average number of accidents and they were close to each other in terms of mean values (2803.58) and (2837.25) respectively. Table (4) and figure (5) shows the mean value and standard deviation of each season of the year.

Season	N	Mean Value	Standard Deviation
Spring	24	3903.96	561.92
Summer	24	3697.42	816.62
Fall	24	2837.25	647.26

Winter	24	2803.58	890.61

Table (4) Average Number and Standard Deviation of Accidents per Season

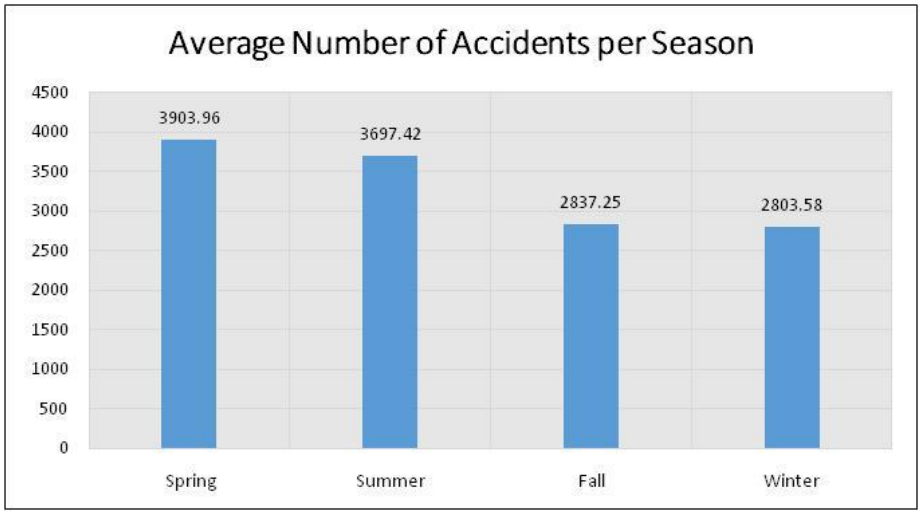

Figure (5) Average Number of Accidents per Season

6.2 ANALYTICAL ANALYSIS

EFFECT OF YEARS AND SEASONS INTERACTIONS

A two way ANOVA analysis was performed to investigate the effect of years and seasons on the number of accidents, in addition the interaction between these two independent variables. The tests showed that there was no significant interaction between these two factors, years and seasons, with a p-value of (0.486). The analysis also showed that there was no significant difference among the years in terms of number of accidents with a p-value of (0.119). On the other hand, the analysis showed that there was a significant difference among the season levels with a p-value of (0.000). Table (5) shows the two way ANOVA results of the effect of years and seasons interaction.

Tests of Between-Subjects Effects					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	40715781.740[a]	31	1313412.314	2.520	0.001
Intercept	1052136489.260	1	1052136489.260	2019.029	0.000
year_m	6286013.156	7	898001.879	1.723	**0.119**
S	23587856.615	3	7862618.872	15.088	**0.000**
year_m * S	10841911.969	21	516281.522	0.991	**0.486**
Error	33351056.000	64	521110.250		
Total	1126203327.000	96			

Corrected Total	74066837.740	95			

a. R Squared = .550 (Adjusted R Squared = .332)

Table (5) Effect of Years and Seasons Interactions

NUMBER OF ACCIDENTS AND SEASONS

A one way ANOVA was performed to compare the season levels in terms of number accidents. The test showed that there was significant difference between seasons with a p-value of (0.000). Scheffe test, which is a Post Hoc test that finds out which pairs of season are significant, showed that spring season had the highest number of accidents followed by summer. However, there was no significant difference between them, with a p-value of (0.817). Winter season had the lowest number of accidents followed by fall. However, there was no significant difference between them, with a p-value of (0.991). In general, spring and summer seasons had significant higher accidents than fall and winter with p-values of (0.002) and (0.001) respectively. Table (6) Shows the one-way ANOVA results and the scheffe pair tests.

Season	**N**	**Mean**	**S D**	**ANOVA p-value**	**95% Confidence Interval for Mean**		**Multiple comparison test**			
					Lower Bound	**Upper Bound**	**Spring**	**Summer**	**Fall**	**Winter**
Spring	24	3903.958	561.924	0.000	3666.679	4141.238	1			
Summer	24	3697.417	816.615		3352.590	4042.243	0.817	1		
Fall	24	2837.250	647.258		2563.937	3110.563	**0.000**	**0.002**	1	
Winter	24	2803.583	890.605		2427.514	3179.653	**0.000**	**0.001**	0.991	1

Table (6) One way ANOVA results and the Scheffe test

REGRESSION MODEL WITH INDICATOR VARIABLES FOR SEASONS AND NUMBER OF ACCIDENTS

The one way ANOVA showed that spring had the highest number of accident rates, therefore, it was taken as the base variable in the regression model. A regression model with indicator variables was performed to investigate the relationship between the seasons in terms of the correlation between them. The model goodness of fit has an F value of (20.63) and a p-value of (0.000), which indicates the significance of the model. The model (R2 = 0.543), which is a good percentage, indicates that 54.3% of total variation in terms of the number of accidents is explained by the model.

The regression model showed that the relationship between spring and summer as well as fall and winter are significant with a p-values of (0.022), (0.000), (0.000) respectively. In addition, it showed that when other variables are held constant, the number of accidents in summer, fall, and winter when compared to spring decreased by (867.268), (5180.958), and (2942.014) respectively. Table (7), (8) Show the results of the regression model with indicator variables and the R2. of the model.

Regression model: Coefficients									
	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
Model	B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	6690.458	250.550		26.703	**0.000**	6187.694	7193.223		
Summer	**-867.268**	366.767	-0.240	-2.365	**0.022**	-1603.240	-131.296	0.853	1.172
Fall	**-5180.958**	903.369	-0.549	-5.735	**0.000**	-6993.701	-3368.216	0.957	1.045
Winter	**-2942.014**	479.766	-0.617	-6.132	**0.000**	-3904.734	-1979.293	0.867	1.154

Table (7) Regression Model results

Model Summary						
Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	F	Sig.
	.737a	**0.543**	0.517	1227.437	20.633	0.000

Table (8) Regression Model Summary

7. CONCLUSIONS

There were different percentages of increase in the number of members at the General Organization for Social Insurance (GOSI) every year between the years 1425H (2004) to 1432H (2011) as 10%, 15%, 18%, 13%, 13%, 14%, and 19% respectively. The average number of accidents increased in general at the first five months of the year, and then started to go down to reach its lowest average at the end of the year.

The two way ANOVA analysis showed that there was no significant interaction between years and seasons, with a p-value of (0.486). In addition, there was no significant difference among the years in terms of number of accidents with a p-value of (0.119), but there were significant differences among the seasons with a p-value of (0.000). The one way ANOVA analysis showed that there was significant difference between seasons, with a p-value of (0.000). Scheffe test showed that spring had the highest number of accidents followed by summer, and that there was no significant difference between these two seasons with a p-value of (0.817). Winter had the lowest number of accidents followed by fall, and there was no significant difference between these two seasons, with a p-value of (0.991). The regression model showed that the relationship between spring and summer as well between fall and winter are significant. When other variables are constant, the number of accidents in summer, fall, and winter when compared to spring decreased by (867.268), (5180.958), and (2942.014) respectively.

In general, spring and summer seasons had significantly higher accidents than fall and winter. Safety regulations at construction sites, preparation, training programs and equipment safety are the

biggest defense against accidents. These measures are more likely to prevent or reduce the number of accidents.

In future studies the effect of other factors e.g., communication, skills, safety and other factors can be investigated in terms of their contribution to accidents on construction sites. In addition, type and cause of accidents can be investigated, and their contribution to construction accidents related to seasons can be tested.

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