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# Workplace Safety and Industrial Accidents in Korea: Forecasting Fatalities for 2018-2019

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**Abstract**
Workplace safety is every workers' basic human right that have to be exercised for the well- being and survival of the employees. Among OECD countries, Korea has the highest fatality rate in workplace. Numerous studies have been conducted on this issue but majority of them were focused on diagnosis of the causes only after the accidents occur. This study analyzes historical workplace fatality data to forecast the industrial accident patterns of the upcoming two years, so that preventive measures to decrease fatality in workplace can be discussed before they happen. Four different forecasting methods are applied and decomposition method produce the least amount of error terms. Result of analysis shows that, during 2018 and 2019, even though there will be a very slight decrease, patterns of industrial accident in Korea are expected to remain similar with previous years. Discussion on more initiatives for accelerating the decreasing trend of industrial accidents in workplace is presented.
**Keywords:** Workplace safety, occupational accident, forecasting fatality of industrial accident, industrial accident in Korea, labor force management in Korea

## 1. Introduction

Being safe from harm and continuing living is at the core of the Human Rights. The Universal Declaration of Human Rights includes 30 articles that cover social, political, and economic rights of human being. And this basic right should be exercised fully in workplace. The Article 23 states work-related human right as "Everyone has the right to work… to just and favorable conditions of work." However, problems with safety issues in workplaces are contradicting with this right. In this study, we will examine workplace safety condition of South Korea. Rate of industrial accidents in Korea is three times higher than OECD average (2.6). Fatality rate from industrial accidents (number of death per 10,000 workers) in 2013 in Korea was 7.3, which was the highest among Organization for Economic Cooperation and Development countries followed by Chile (5.9) and Turkey (4.8) (Moon, 2015). The high fatality rate is not only a human right issue but also a serious problem in social and economic

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life as well. Gong (2014) reported that industrial accidents caused 17.5 trillion won (more than 15 billion dollars) expenses to society and corporations.

Korea's economy has experienced rapid growth and still continues to develop, and workplace safety is an urgent social problem required to find solution. For Koreans, watching news which report death of employees or laborers in work site is not something unfamiliar. A cleaner in a subway station died after being hit by train (Seok, 2017) and a worker died after getting pinned under construction material (Park, 2017) on the same day. Three weeks before, four workers were killed from powerful tank explosion of a shipyard (Chyung and Park, 2017).

Moon (2015) reported that in Korean workplaces every 5 hour 1 employee is losing his or her life because of industrial accidents. In average, 250 employees are injured everyday and 5 among them die. Accidents consist of being caught in facilities or equipment problems, slipping on the floor, stumbling on something, or falling from a height.

Why is fatality rate of industrial accident this much high in Korea? Moon (2015) pointed the reason as '*bbali bbali*' syndrome (hurry hurry, hastiness). Koreans tend to be in a hurry in their work life and daily life. While trying to make everything fast, safety issue is ignored. Also, this syndrome is negatively associated with employees' work productivity. Bae (2007) reported that 63% of office workers responded they get stress and tend to make mistakes while working hasty. According to Cho (2007), Korean employees are not safety conscious, and they act before thinking. Also, by citing the interview with Borin, CEO of Pilz Korea, Cho reported that law on safety implementation is not in advance in Korea. Another reason of high fatality rate can be found from Korea's history of economic development.

### 1.1 Development of Korean Economy

It is noteworthy that Korean conglomerates, which are called *Chaebol*, played crucial role in economic development of Korea. After the independence in 1945, a few Korean-owned firms began to take initiative in economy. The government had beneficial policies to these firms and banks also provided privileges on borrowing loans. These firms could build their basic foundation for growing into conglomerates in the future.

After the Korean War ended in 1953, Korea's economy has been rapidly growing. Especially during the 1960s, nation-wide economic development movement named '*Gongjang Saemaeul Undong*' made the country as one of the fastest growing economy. Form and Bae (1988) illustrated that as a result of this movement Korea has achieved unprecedented economic growth.

The growth of *Chaebol* was mainly based on two factors; foreign loans and support from the government. Beginning from exporting light products such as wigs and textile materials in 1960s, their business has been transferred to heavy industry, shipment, and chemicals in 1970s and to semiconductors and technology-intensive products in 1980s.

However, Asian financial crisis attacked Asian countries at the end of 1990s, and Korea was not exceptional. Foreign capital moved out from Korea, and foreign exchange reserve of the country was not enough to pay the loan. Therefore, Korea had to ask financial aid to International Monetary Fund. In the period between 1998 and 1999, many of public companies became privatized, corporations cut the employees' wage, and employees were

laid off in great numbers. Some of the corporations were sold to foreign funds, and stock markets were severely damaged due to collapse of bubble. Today, after approximately 20 years Korean economy has improved greatly in comparison to the economic condition at that time.

Korea is a member of Asia Pacific Economic Cooperation, World Trade Organization, Organization for Economic Co-operation and Development, and The Group of Twenty. Nominal GDP of the country is $1.38 trillion in 2015, ranked as 11th in the world (The World Bank, 2016). Also with its highly developed technology and investment on research and development, the country is ranked as the first on innovation index in 2015 (The Bloomberg Innovation Index, 2015).

OECD (2015) reported that longevity of Korea is 82 years old, 2 years higher than OECD average. Also, 89% of men and 81% of women have completed high-school education, which is higher than OECD average. Korean students aged 15 recorded the highest score of Programme for International Student Assessment (PISA). The emphasis on education contributed on economic growth and high-tech economy.

### 1.2 Reasons of Industrial Accidents in Korea

Looking at the indices of the country; high GDP, high literacy rate, member of OECD and G-20, internationally-known successful multinational corporations such as Samsung, LG, and Hyundai, it seems that Korea is a highly developed country. However, when it comes to industrial accidents, the country is still developing.

Economic factors are main reasons of high fatality in workplaces. Problems such as too much pressure on outcome instead of process, poorly designed work places, obsolete equipments, great amount of industrial pollution, lack of concern on employees' health, and not enough safety-related regulations, all of these are due to rapid, short-sighted, and outcome-focused economic development.

Some part of the responsibility of increasing fatality in workplaces may lie on the fact that Korean economy is developing with new industries and new work forces. However, great portion of the responsibility lies on the government, legal agencies, and firms. Lack of regulations on workplace safety and laborers' safety results increase in industrial accidents. Even though there are some regulations, firms do not follow the legal obligations and excuse themselves by blaming high cost and time imposed by the obligations. Yoon (2014) reported that reasons of high industrial accidents is not only caused by few time allowed for the society to think of safety issue while focusing on fast growth, but also because of firms' tendency to perceive the cost for safety as 'loss' instead of 'investment'. Firms generally think that cost of handling after accidents is much less than prevention cost before accidents. The reason of explosion in shipyard was found as the firm's overlooking attitude toward compliance of safety-related regulations and cost-cut policy toward management of safety-related materials (Choi, 2017).

## 2. Literature Review

Workplace safety issue is a widely studied and internationally discussed subject in literature. The study of Nytro, Saksvik, and Torvatn (1998) and Saksvik, Torvatn, and Nytro (2003)

aimed to understand how well Norwegian enterprises are following required safety rules ever since new safety regulation was set on January 1992. Enterprises' operation on health and safety issue was examined from top management level, internal employees' level, external regulatory and customer level. The studies reported that for firms at the beginning stage of following the new regulations and internal management is the most important factor for building safety-related system in enterprises. Amuedo-Dorantes (2002) suggested that high accident rate in Spain should be examined regarding the aspect of employees and workplaces. Through interviews with both employers and employees, the author reported that working condition variable has the strongest effect on workplace safety issue than other variables such as location of the workplace, industry of the job, and employee characteristics.

Ergör, Demiral, and Piyal (2003) analyzed occupational accident data from 1995 to 1997 in Turkey. They reported that working conditions, sectors, regulations, and resource utilization are important factors for preventing accidents in workplaces. In the study of Unsar and Sut (2009), rate of industrial accident in Turkey from 2000 to 2005 was assessed and compared with that of other countries. They presented that fatality rate during the period has fluctuated and manufacturing and construction sector are more hazardous than other sectors.

Suzuki et al. (2004) studied the relationship between psychological health, shift work, and occupational accidents of nursing staffs in Japan. The study found out that the staffs with frequent work shift are more likely in poor condition of their psychological health, and these staffs show high rate of occupational accident. Berryman, Lukes and Keller (2009) also illustrated that health firms increasing work shift and working hour in the United States can pose threat on high occupational accident of nursing staffs.

Similar with international literature, studies on workplace safety in Korea discuss causes of accidents in detail. Jeong (1998) analyzed the data of occupational injury in Korea from 1991 to 1994 in terms of employees' demographic factors such as age and tenure, accident characteristics such as causes and types of accident, and finally firm's characteristics such as the number of employees and industry which the firm is working in. The study showed that majority of the accidents are caused by falling from a height, and fracture is the most common symptom of the injury. Also construction sector experienced the greatest amount of occupational accidents. Study of Im, Kwon, Kim, Kim, Ju, and Lee. (2009) also reported the similar result; occupational injury data from 1997 to 2004 in Korea presented that employees are exposed to injury most frequently in construction sector. This is considered due to the dangerous work environment, and comparatively elder employees of the sector than employees in other sectors. Occupational accidents in manufacturing sector, especially textile companies with less than 50 employees were the subject of the study of Lee and Jeong (2008). The study reported that employees in the age of their 40s, and employees with short tenure less than 1 year are more exposed to industrial accidents. Also, majority of accidents were related with working environment such as materials or clothes got caught in manufacturing equipment.

Even though studies on occupational accidents cover wide range of subjects and diverse variables, they are mainly focused on retrospective analysis of accidents, not future forecasting. Those retrospective studies have difficulty in suggesting a proactive attitude

which is necessary to prevent the accidents. Therefore, by forecasting the future trend of industrial accident, this study attempts to propose appropriate alternatives to decrease fatality in workplaces.

When it comes to forecasting techniques in accident-related studies with time-series data, exponential smoothing method and Autoregressive Integrated Moving Average Model (ARIMA) were commonly used. In the study of Helfenstein, Ackermann-Liebrich, Braun-Fahrländer and Wanner (1991), they used ARIMA to examine and forecast the relationship between environment pollution and respiratory diseases in children. In the study of Zheng and Liu (2003), time-series method especially exponential smoothing and ARIMA model were considered as frequently applied forecasting methodologies. They illustrated the characteristics of exponential smoothing method as future trend is forecasted based on weighted moving average of previous data. Quddus (2008), in the study of forecasting road traffic accidents in UK applied Interger-Valued Autoregressive (INAR) Poisson model, a new model over ARIMA for time-series data.

In this study, diverse forecasting techniques such as moving average, exponential smoothing, decomposition, and regression were implemented to observe the data pattern of industrial accident and accurately forecast the fatality in workplaces in Korea, so that preventions can be developed for future industrial accidents. The forecast result is expected to be helpful for both legal authority and firms to aware of the severity of the condition, the importance of setting more regulations, and the urgency of following the rules for employee safety. The analysis may provide benefits to employees as well; by learning the variables that can cause fatality in work environment, employees can be careful with the causes of the accidents.

## 3. Methodology

### 3.1 Data

The fatality data were collected from Ministry of Employment and Labor in Korea. In the data set, fatality in workplaces is the sum of 'number of death from occupational accidents' and 'number of death from occupational injury'. SPSS 21.0 was used in the data analysis and forecasting. The regulation on the method of calculating the number of fatal accidents has been changing frequently. Recently the data from January 2011 have used the same standard. Therefore, the data in the study are from the first quarter of 2011 to the second quarter of 2017. Yet, the data had two missing observation; the third and fourth quarter of 2012. Missing data imputation was conducted through regression analysis. The regression equation produced fatality of third quarter as 468 and for the fourth quarter as 466. Combining the fatality of original 2012 data and imputed data, the total number of accident is very close to the total amount reported by Ministry of Employment and Labor. Therefore the regression imputation was reliable. Table **1** represents descriptive characteristics of the observed fatality data.

**Descriptive Statistics**

| | Statistic | Std. Error | Bootstrap[a] | | |
|---|---|---|---|---|---|
| | | | Bias | Std. Error | 95% Confidence Interval |

| | | | | | | Lower | Upper |
|---|---|---|---|---|---|---|---|
| ObservedFatality | N | 26 | | 0 | 0 | 26 | 26 |
| | Range | 170 | | | | | |
| | Minimum | 405 | | | | | |
| | Maximum | 575 | | | | | |
| | Mean | 479.73 | 8.137 | .29 | 8.28 | 463.96 | 496.77 |
| | Std. Deviation | 41.490 | | -.977 | 5.309 | 30.579 | 50.829 |
| | Variance | 1721.405 | | -51.998 | 433.385 | 935.055 | 2583.623 |
| | Skewness | .204 | .456 | -.038 | .368 | -.618 | .873 |
| | Kurtosis | -.061 | .887 | -.085 | .683 | -1.187 | 1.528 |
| Valid N (listwise) | N | 26 | | 0 | 0 | 26 | 26 |

a. Unless otherwise noted, bootstrap results are based on 1000 bootstrap samples

Table 1. Descriptive Statistics of Observed Fatality

Mean of the data is 479.73, standard deviation as 41.490. With 95% of confidence level, the fatality in a quarter during the period is moving between approximately 464 and 497 workers. From 2011 to the second quarter of 2017, the lowest amount of fatality is 405 whereas the highest fatality is 575. Figure 1 below shows sequence chart of observed fatality. The number of death from industrial accident showed increasing trend from 2011 yet turned decreasing after the second quarter of 2012. Although the first and second quarter of 2017 show slight increase compared with the previous year, the whole data in general show additive decreasing trend. Since the data include both 'number of death from occupational accidents' and 'number of death from occupational injury', the authors assumed that the data represent seasonality; accidents or casualties that occur in the workplace is very likely to be influenced by weather. Also examination of sequence chart shows that number of fatality generally reaches its peak for every second or third quarter of a year.

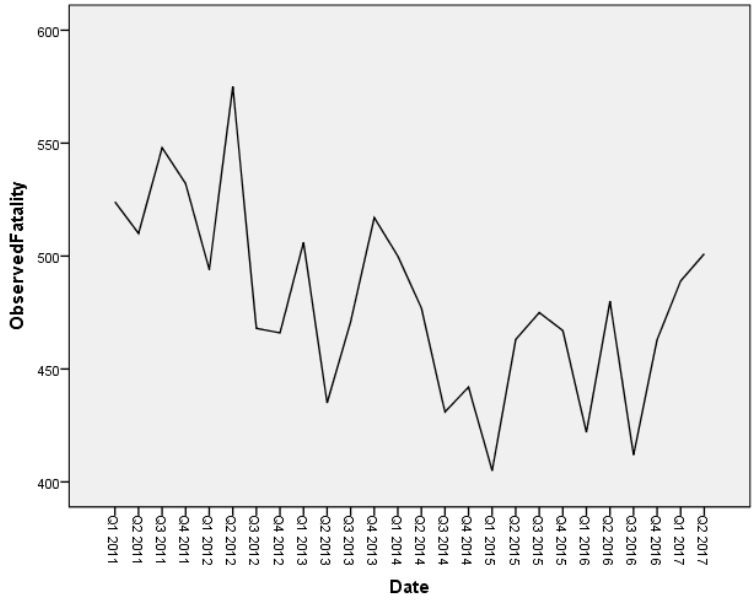


Figure 1. Sequence Chart of Observed Fatality

### 3.2 Model Fitting

Considering the trending pattern of data, short time horizon for forecasting period, and better understanding of the result (Hanke and Wichern, 2009), moving average, exponential smoothing, decomposition, and regression forecasting techniques were used. In order to measure the forecasting errors, 4 quarter period – Q3 2016, Q4 2016, Q1 2017, and Q2 2017 – were used as holdout period. MAPE, MAD, MSE, and RMSE were used as accuracy measures.

#### 3.2.1 Moving Average

Prior moving average with span 4, 6, 8, and 12 were examined. Among the different spans, both MA6 and MA8 showed the lowest forecasting error with slight difference. Specifically, MA6 had the lowest forecasting error in MAD and MAPE whereas MA8 had the lowest forecasting error in MSE and RMSE. Forecasting errors during the holdout period of MA6 and MA8 were calculated and accuracy measures are presented on Table **4**.

#### 3.2.2 Exponential Smoothing

Exponential smoothing method with Simple, Holt's linear trend, and Damped trend were examined. Also seasonality methods such as Simple seasonal, Winter's additive and Winter's multiplicative were included in the analysis. Close examination of the accuracy measures showed that Simple seasonal method has the lowest errors. Forecast errors during the holdout period are reported on Table **4**.

#### 3.2.3 Decomposition

In order to conduct seasonality decomposition, SPSS requires at least four full quarterly data. Therefore, the observed fatality of the third and fourth quarter of 2017 was required. Since it is easy to implement the analysis and understand the result, exponential smoothing method was conducted to predict the fatality of the period. Winter's additive model showed the highest R square and lowest accuracy measures. The model produced 429 and 443 fatalities of

the last two quarter of 2017. Trend, Seasonality, Irregularity and Cycle factors were all traced out and recalculated by additive way. Seasonal factors showed that in first and third quarters approximately 4 less workers and 14 less workers die than average, whereas second and fourth quarters 14 and 3 more employees die than average. This is partially consistent with the previous examination from sequence chart; the number of fatality reaches its peak either in second or third quarter of each year. Seasonality and irregularity was removed by centered moving average. When both span 4 and 6 were imputed and examined with sequence chart, span 6 showed peaks were removed, which means that centered moving average with span 6 was an effective method to trace out seasonality and irregularity. Time variable was computed beginning from the first case. The outcomes of centered moving average were regressed on time to determine the trend. Then the regression equation was, $\hat{Y} = 524.734\text{-}3.778*\text{Time}$. Cycle component was computed as subtracting outcome of centered moving average from trend component. Sequence chart of cycle factor presented that the data are left with two cycles. Cycle factor forecast was conducted with damped trend exponential smoothing method which showed highest R square and lowest forecasting errors. MAPE, MAD, MSE, and RMSE of the decomposition method are on Table **4**.

### 3.2.4 Regression

Dummy variables related with government's regulations were used as the main independent variables of the forecasting.–

Contract variable: On March 2011, Korea Occupational Safety and Health Agency made a contract with private accident prevention organizations. These are organizations which monitor implementation of safety related activities in workplaces, and which repair machineries and equipments of factories (Korea Occupational Safety and Health Agency, 2015). Special contract with government and monitoring agency is expected to be helpful in decreasing number of fatalities in workplaces. This variable was effective from Q2 2011.

Guide variable: On September 2012, Korean government issued a rule that employers must give guidance to employees about how to handle the electronic and technological equipments in the workplace (Korea Ministry of Government Legislation, 2013). The legislation aimed to increase employees' awareness on safety, especially with machineries and electronic equipments. The variable was reflected from Q4 2012.

Winter Report variable: Ministry of Employment and Labor issued a report on '2013 Safety Guide for winter' on November 2013 (Ministry of Employment and Labor, 2015). The report included expected weather during the winter, general pattern of industrial accidents during the season, and required preparation and safety check for workplaces. This variable was reflected from Q4 2013.

Regulation variable: The government widened the coverage area of 'Occupational Safety and Health Acts' from January 2014 (Korea Ministry of Government Legislation, 2015); frequency and types of education was increased, number of sectors that is require to keep safety professionals at work is increased, and firms with less than 5 employees were included in the new act. The variable was reflected from the Q1 2014.

Lastly, seasonal dummy variables and time related variables such as Time, Time2 (Time*Time), Division (1/Time), and InT (LnTime) were computed. First all the eleven

variables were included in the model. For the model decision, collinearity of the variables with VIF, independency of residuals with Durbin Watson, and statistical significance were examined in order. Since the data have seasonal pattern, seasonal dummy variables were kept in the model regardless of significant value. The final model included contract variable, guide variable, regulation variable and seasonal dummy variables.

The model explained 32% of the variance and was statistically significant $F(6, 19) = 2.997$, $p = .031$. Table 2 and Table 3 represent model summary and coefficients of the each variable. Forecasting error of the regression method is reported on Table **4**.

**Model Summary[b]**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Durbin-Watson |
|---|---|---|---|---|---|
| 1 | .697[a] | .486 | .324 | 34.113 | 2.108 |

a. Predictors: (Constant), Q2, Q3, Q4, Contract, Guide, Regulation

b. Dependent Variable: ObservedFatality

Table 2. Model Summary of Regression Analysis

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Tolerance | VIF |
| 1 | (Constant) | 524.000 | 34.113 | | 15.361 | .000 | | |
| | Q2 | 15.171 | 19.077 | .165 | .795 | .436 | .625 | 1.600 |
| | Q3 | -12.376 | 19.894 | -.128 | -.622 | .541 | .637 | 1.570 |
| | Q4 | 8.591 | 19.923 | .089 | .431 | .671 | .635 | 1.574 |
| | Contract | -5.197 | 39.252 | -.025 | -.132 | .896 | .785 | 1.273 |
| | Guide | -43.798 | 21.085 | -.478 | -2.077 | .052 | .512 | 1.954 |
| | Regulation | -19.457 | 18.043 | -.238 | -1.078 | .294 | .553 | 1.808 |

a. Dependent Variable: ObservedFatality

Table 3. Coefficients of Regression Analysis

### 3.2.5 Model Selection and Forecasting

The table below reports accuracy measures from the four forecasting methods.

| | **MAPE** | **MAD** | **MSE** | **RMSE** |
|---|---|---|---|---|
| **MA6** | 7.06 | 32.8 | 1261.98 | 35.52 |

| | | | | |
|---|---|---|---|---|
| **MA8** | 7.3 | 34 | 1254.96 | 35.43 |
| **Simple seasonal** | 6.2 | 28.5 | 901.5 | 30.02 |
| **Decomposition** | 4.65 | 21.5 | 607 | 24.64 |
| **Regression** | 5.12 | 23.8 | 737.75 | 27.16 |

Table 4. Accuracy Measures of the Forecasting Techniques

From the accuracy measures, decomposition method had the lowest forecasting error among all, followed by regression, simple seasonal exponential smoothing, MA6 and MA8. Fatality in industrial accident of the upcoming two years is forecast from decomposition model as Table **5**.

| 2017 Q3 | 2017 Q4 | 2018 Q1 | 2018 Q2 | 2018 Q3 | 2018 Q4 | 2019 Q1 | 2019 Q2 | 2019 Q3 | 2019 Q4 |
|---|---|---|---|---|---|---|---|---|---|
| 448 | 464 | 455 | 470 | 440 | 454 | 445 | 459 | 427 | 441 |

Table 5. Fatality Forecasting for the upcoming Two Years

The Figure 2 below represents data movement of original observed fatality and decomposition forecast until the end of 2019. The forecast outcome refers that during 2017, 2018 and 2019 the fatality from industrial accident will remain similar with recent years and only slightly decrease.

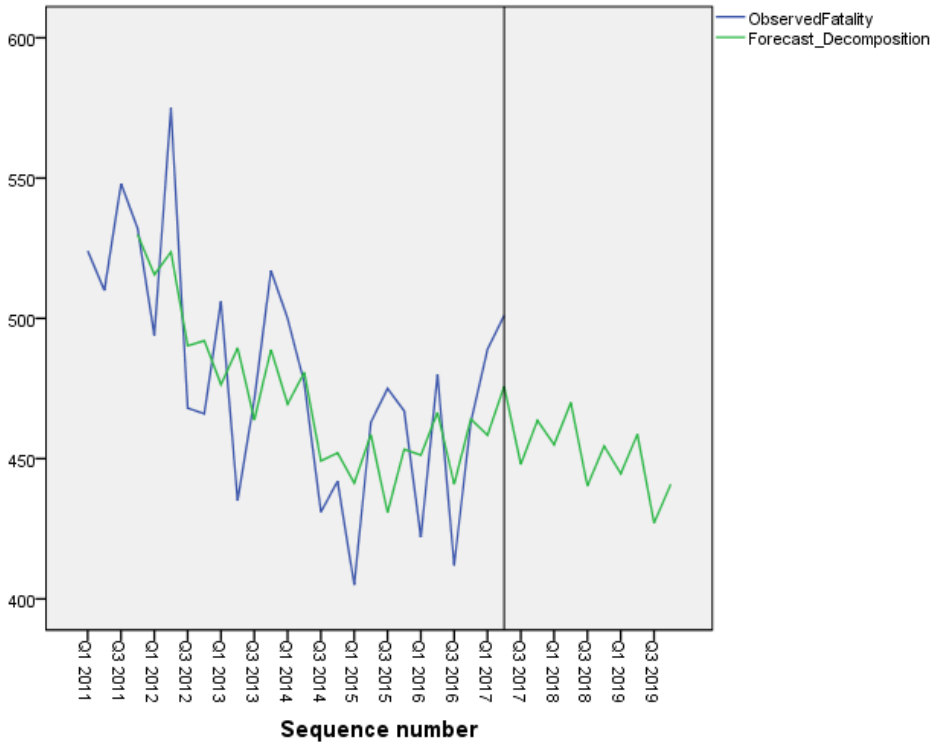


Figure 2. Sequence Chart of Observed Fatality and Forecast Decomposition

## 4. Results and Discussion

The lowest forecasting error produced from decomposition method implies that the fatality data have trend, seasonal, and irregularity components and the method was suitable to reflect the importance of individual components. Decomposition method forecast that 1902 employees in 2017, 1819 in 2018, and 1772 in 2019 will lose their life from industrial accident. Overall for the upcoming two years fatality of industrial accident will be moving similarly with previous years. A slight decrease is expected but high fatality rate will persist. Considering the importance of every single human life and industrial accidents' negative effect on family, social, and national levels, it is crucial that fatality of industrial accident should be decreased more. For the following years, more than 150 employees will lose their life every month and 5 workers will die in a day. Beyond the humanistic concern of the value of the employee's life and great sorrow of his or her families, it can be seen that loss of human resources is beginning to cause an exponential threat to Korean economy as well.

When Korean economy is examined, it can be clearly seen that the country suffers from lack of natural resources. U.S. Energy Information Administration (2017) reported that South Korea rely on 97% of overall energy demand on imports due to insufficient domestic resources; "Korea is the second-largest importer of liquefied natural gas…the fourth-largest importer of coal…fifth-largest importer of crude oil and condensate." Kim (2014) also reported that 99% of metal resources of Korea are dependent on imports and the country's energy security is very unstable.

Despite insufficient natural resources, Korea's competitive strength lays in its highly qualified human resources. D. T. (2011) reported that 82% of high school graduates go to university, so Korea has the highest adult literacy rate among OECD countries. Hiatt (2011) also reported that among Koreans who are in the age between 25 to 34, more than 60 percent of them has received university education or more. This makes the country as the sixth most educated country in the world (Sauter and Hess, 2012).

There are two important problems that have to be considered for effective nationwide human resource management. First, there is imbalance between supply and demand of labor force. Majority of the labor force tend to prefer office environment. Even though youth's (aged between 15 to 29) unemployment rate is as high as 10%, small and medium sized firms have difficulty in hiring new employees (Y. J. Kim, 2017). The tendency is relatively strong especially in manufacturing and construction sector. Therefore, it is very likely that many workers are old in factory facility or construction site and this may increase fatality of industrial accident. Study of Jeong (1998) also found out that construction workers aged above 45 year are more exposed to the danger of industrial accident. Secondly, the birth rate of Korea is the lowest in the world and it imposes serious labor force problem for a sustainable economic development in the long run. For the number of children born to women aged 15 to 49, Korea recorded the lowest as 1.19 (OECD, 2016). The number of birth is sharply decreasing; it was in the 600,000 and 700,000 range in 1980s and 1990s but plummeted after 2000s as 500,000 range between 2001 and 2002 and 400,000 in 2016 (S. Kim, 2017).

Considering the two problems, the importance of effective labor force management is getting more critical for Korea. Due to the difficulty of the job, youths do not apply for jobs in production facilities or construction site, thus the average age of employees in the sectors is higher than other sectors, and elderly employees tend to be exposed more on occupational injuries. Low birth rate means fewer amounts of labor force in the future, and this increases necessity to find alternatives to safely manage labor force.

From the regression model of the study which produced second lowest forecasting errors, it was found that Contract variable, Guide variable, Regulation variable and seasonal dummy variables can predict one third of fatality in workplaces. Therefore, it can be assumed that in order to further decrease the fatality of industrial accident, government's active intervention such as monitoring workplace safety, encouraging employers to give safety related guide to employees, and setting safety related regulations are necessary.

The study of Harvey and Durbin (1986) also supported the importance of government's intervention on decreasing casualties of car drivers. Amuedo-Dorantes (2002) pointed out that regulations should not merely stating necessary activities but clearly describing what to do, how to do, and what are negative incentives if firms do not comply with the regulations. Also the author stated that the legislation should be in a way to encourage employees' involvement in safety related activities. Pringle and Frost (2003) claimed that efficient bureaucratic management of safety issue and overall implementation system are as important as creating safety legislations.

Government's intervention should not only be limited as setting up new regulations or laws. As criticized by Jeong (2016), government's assessment system for firm's safety-related aspects makes firms hide actual industrial accidents. Since government gives advantage to firms which record low industrial accident rates for winning big projects or bids, firms tend to conceal occurrence of occupational accidents. In this system, injured employees are left with financial and physical burden without anyone who takes responsibility of the injury. This attitude of firms and government is not only unethical but also harms employees' well-being and as a result negatively influences Korean labor force in the long run. Therefore, government should consider revising the current regulations. Likewise, government has to give financial support to firms to renew old facilities and to enforce the hiring safety-related professionals in firms. In other words, organizational climate should be encouraged to become safety aware. Neal, Griffin, and Hart (2000) found that safety outcome is strongly related with safety climate of an organization. As organizations are encouraged for more open communications regarding safety issues, employees' motivation, knowledge, and skills about safety will become more part of the shared organizational values, thus safety condition in the workplaces can be improved.

### 4.1 Limitations of the Study

Though decomposition method produced the least forecasting error followed by regression model with one third of explanatory power for fatality in workplaces, it is noteworthy to consider several things to improve the model. First of all, due to the problem of data availability only dummy variables were used in the regression analysis. Second, unstandardized coefficient value showed that contract, guide, and regulation variables are

negatively related with fatality. This might be because seasonal variables were pushed into the model and only dummy variables were considered in the model. These two limitations can be improved if other possible predictors are included in the analysis.

Moon (2015) reported that more than 80% of accident occurs in the firms that have less than 50 employees. Jeong (1998) also found that workers in small companies face higher risk of industrial accident. Jeong interpreted the result as smaller firms may not have enough capital to renew the facility or to set up protective system. Another possible predictor is working hour. Lee, Choi, Lim, Kim, and Jung (2014) presented employees who are working more than 52 hours per week have 2.5 times more possibility of exposure to industrial accident. This might be due to the increased stress and fatigue of the employees. Sector variable can explain fatality of industrial accident as well. As reported by the study of Im, Kwon, Kim, Kim, Ju, and Lee (2009) and Jeong (1998), construction sector takes the highest portion of industrial accident in Korea. Painters, plasterers, and scaffolders are highly exposed to accidents such as electric shock and falling from a height. Therefore it is expected that if variables including size of a firm, working hour, and industry sector are considered in the regression model, the model will have higher explanatory power and produce more reliable forecasting result.

## 5. Conclusion

Overall, main purpose of the study was to forecast fatality from industrial accident in Korea based on time series data and to suggest appropriate direction to decrease fatality. The data available was from the first quarter of 2011 to the second quarter of 2017. Moving average, exponential smoothing, decomposition and regression methods were conducted. The criteria to decide best forecasting model was MAPE, MAD, MSE and RMSE. It turned out that decomposition method produced the least forecasting error followed by regression analysis, simple seasonal exponential smoothing, and moving average method.

The forecast values reflected the similar movement of fatality in occupational accident until 2019. However, fatality rate should be decreasing more rapidly. Government's intervention on the issue is a must; the intervention might include setting coercive laws and regulations on safety-related issues to firms and employers, encouraging safety climate of organizations, supporting firms financially for renewing facilities, and beginning campaigns to increase safety-awareness for employees.

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