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WEATHER INDEX FOR CONSTRUCTION INJURY

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ABSTRACT

The Korea has definite four seasons each having different temperature, humidity, and other weather factors. In that, the KMA(Korea Meteorological Administration) has been released diverse weather indexes from life style to industry weather indexes. However, indexes released by the KMA has rough numbers(indicators) which are not from data of industry when it comes to construction and other occupational injury related indexes. By the way, an occupational injury has been world widely studied to protect employees' life and labor power since an injury may cause death or partial disable. Especially, in construct area, an occupational injury is the most important concerns of construction companies. In this research, I merged weather data from KMA and occupational injury data from the KOSHA(Korea Occupational Safety and Health Agency) to make safety weather index with optimal scaling methodology. As a result, I made seven grade safety weather index which divided by injury type in construction industry.

Keywords: *Occupational injury, Construction injury, Weather index, Safety weather*

1. INTRODUCTION

1.1 Weather analysis

The Korea Meteorological Administration has been developed and released diverse weather related information not only common information such as temperature and humidity but also life indexes such as ultraviolet for outside activity, food poisoning, sensory temperature, laundry washing index, and other life related indexes [1]. Although those have not specific grades, 5 grades including low, normal, high, very high and danger, Koreans utilize those indexes as parameter of their lifestyle. Especially, today, the concentration of fine dust index becomes core index for outdoor activities such as running, picnic, and others.

Since the Korea Meteorological Administration (KMA) has released diverse and life practical indexes, diverse life familiar indexes have been continuously developed including convergence indexes meaning indexes for special purpose such as pollution index for factories and fine dust indexes for users who concerns air they breath and those who are mostly living in populated city such as the Seoul. Table 1 below shows life-style weather indexes those KMA release by website and smartphone application. Those index service supports open API that could facilitate diverse applicable services by not only government organizations but also weather information user companies such as building construction companies and airline companies

TABLE 1: KMA LIFE WEATHER INDEX SERVICE

Segment	Index
Life Weather Index	Ultra Violet rays Index
	Food Poisoning Index
	Heat Index
	Rotten Index
	Discomfort Index
	Wind Chill Index
	Freeze and Burst Index
	Frostbite Possibility Index
	Atmospheric Diffusion Index

Although those indexes are statistically analyzed and released to public by the administration, there have been diverse needs to analyzed weather data and convergence research with other industry data [2]. The weather forecasting and current weather reporting is already widely used itself. For example, airport control tower utilize wind speed and direction, fog, typhoon location and others for airplane landing and take-off. There are strict regulation for airplane related to common weather factors. However, those are practices for weather information itself not convergence utility.

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1.2 Occupational Injury and Construction

In 2016, an occupational injury and illnesses rate of the Korea is 0.49% and death rate is 0.96% when accidental death is 0.53% of them, meaning one of a hundred of employee is dead when he or she works [3]. In numbers, dead by accident employee is 969 which is 1.5% increase than prior year when number of accidental injury employee is 82,780 which is 0.7% increase [3]. The number looks not much for countries having more population then the Korea. However, the Korea has about 45million population and is aging society meaning work force is decreasing year by year. In that the Korea government efforts to decrease occupational injury and illness especially injuries those are much easier to manage than illness because illness is hard to control with system.

An occupational injury and illnesses are one of major concerns of government not only the Korean but also other major countries [4]. The United States has been managed nonfatal injuries and illnesses since 2003 and now, has 40 percent decreased TRC(Total Recordable Cases) [3][4]. Although the dramatic decrease happens on non-fatal injuries and illnesses area where healthcare and manufacturing industry causes most cases, the decreasing rate and speed is worthy of close attention when it comes to the England's high non-fatal and fatal injury and illness rate [5]. Whether it's fatal or non-fatal, an occupational injury and illnesses are hardly managed and monitored by government agency in each countries.

Although each country has own different economic and environmental condition which causes unique occupational injury management system, industries those causes injuries are similar: healthcare, construction and manufacturing. Figure 1 shows number of non-fatal occupational injury and illness employee in the Korea. In the graph except 'other industry' which means service industries such as health care, social welfare, cooking, and hotel, a manufacturing and construction injury and illness victims are dramatically higher than other industries even it's non-fatal. Unlike to the Korean, in the United States, construction industry has relatively lower than other industries [2][3].

Figure 2 shows a fatal occupational injury and illnesses in the Korea. Unlike to non-fatal, a construction, mining, and manufacturing industry is much more higher than others even than service industry (other industry in figure 2) [2][3]. Although the Korea has diverse industries, it still has labor oriented industry such as building construction as a major industry which causes frequent accident as one can see figure 2 because there are more manual labor workers in the industry [6].

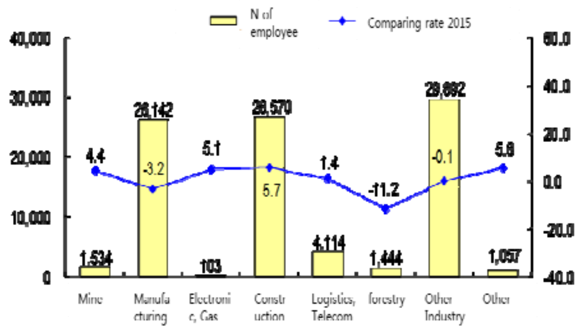

Figure 1: Korean Non-Fatal Occupational Injury & Illness

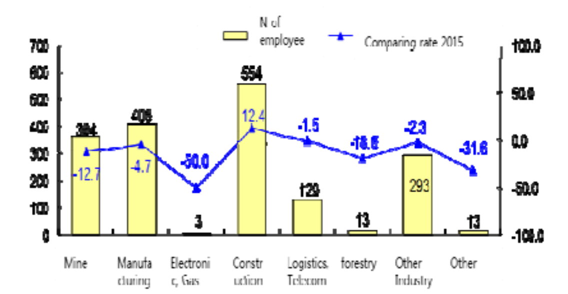

Figure 2: Fatal Occupational Injury & Illness in the Korea

Because of the higher accident case of construction, mining, and manufacturing industry, the Korean research for occupational injury and illness focuses on those industries [7]. Figure 3 shows reasons of fatal occupational injury in the Korea that the most high rate in 'fall'. The figure illustrates purpose of this research because falling death happens barely in manufacturing or mining industry. In manufacturing and mining industry, they have less high attitude work environment than construction such as building.

Although there are high attitude facilities in manufacturing industry, accidents happens not to manufacturers but to constructors may works for manufacturing company or contracted construction company. Those accidents at figure 3 mostly happens outside working environments those are affected by weather conditions such as temperature, humidity and rain amount and snow. In this research, started with understanding above situations leads relationship between weather and construction worker's occupational injury.

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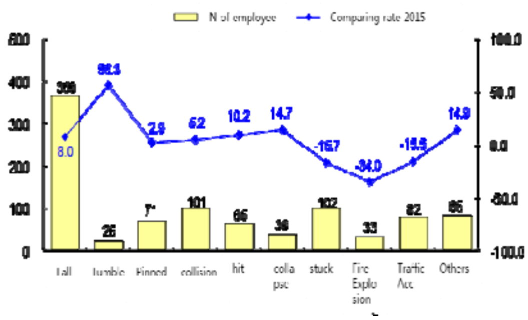

Figure 3: Reasons of Fatal Occupational Injury

2. RELATED RESEARCHES

2.1 Weather Information for Industries

The Korea Meteorological Administration continuously release industrial weather indexes for five industries: agriculture, construction, energy, logistics and hightway at table 2 [2]. There are four indexes for construction area having the most many indexes with logistics area because those two industries' work safety relates to weather condition that lead detail indexes for them. Although those are developed by huge data of the administartion, those indexes are not from convergence way, meaning it's from data of the administration itself but not joinning other administration or facilities' database such as the Ministry of employment and labor that we used for this research.

Table 2: KMA Industrial Weather Index

Industry	Index Name
Agriculture	Agriculture Facility
	Pesticide Spray
Construction	Foundation Construction
	Frame Construction
	Stone Construction
	Finishing Construction
Energy	Heating Energy
	Cooling Energy
Logistics	Fruits, Vegetables
	Sea Foods
	Ice cream
	Transport
Highway	Highway

In that, especially for construction area, there are very rough grades as one can see at table 3. There are only three grades: bad, normal, and good for construction indexes. Below table 3 shows frame construction weather indexes and description. As one can see, each grade looks have specific numbers of guide, however, those are very similar to other outside activity index guide numbers such as indexes for outside leisure activities and also deales with only amount of rain and temperature.

Besides the weather indicators issue above paragraph, the KMA construction index has other limitation: type of injury. The index comes from type of construction such as frame, stone, finishing and foundation but not from types of injuries. That means, it is activity recommendation index rather than 'safety weather index'. As one can see at Figure 1 to 3, an occupational injury rate is differenciate by types of reason of injuries even it is fatal or non-fatal. Those graphs shows injuries should be analyzed by each, and also, wetather factor should be located on each injury type data rather than type of construction.

Types of construction in FMA indexes would not directly be related to occupational injuries because all types of injuries could be happened in every types of construction. For example, the injury cause 'fall' in construction industry, may happened all four: foundation, stone, finishing, and frame construction environments. The cause 'fall' does not depends on a type of construction but a type of work on injury day. Not only finising contruction has high height position work, but also other three could have. Furthermore, cause 'fall' may be happened in low height.

Table 3: Frame Construction Weather Index

Grade	Weather Condition	Description
Bad	Over 5mm rain per day or minimum temperature under 0℃ or maximum is over 30℃	Safe and process effectiveness is very low. Better to not work.
Normal	Day rain amount under 5mm or daily average temperature over 5℃ or under 17℃	Construction is possible

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Good	No rain and minimum temperature over 5℃ and maximum is under 25℃	Good for construction

Although indexes of KMA about construction is not suitable to prevent occupational injuries, KMA released open API(Application Program Interface) for weather raw data and open there weather data via website. The Korea Open Data Council(ODC) that supports and make regulations for opening public data released related law in 2013 [11]. The weather dataset which opened with open API is contactable to download with text format to put into any types of database that user utilize. Figure 4 shows sample dataset of KMA for wind speed. As one can see, it has observation spot number and wind speed data recored by every one hour. In this research, I utilize KMA past 5 years raw data about temperature, humidity, amount of rain, wind speed, and amout of snow.

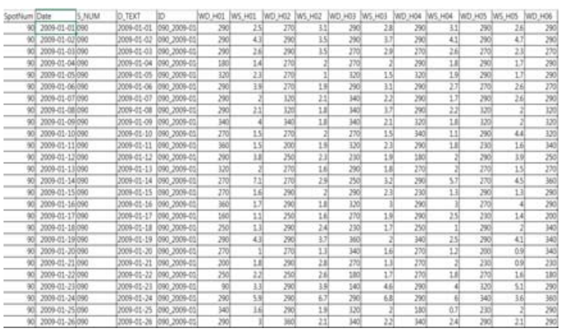

Figure 4: KMA Sample Dataset of wind speed

2.2 Optimal Scaling

Gifi (1990) offers a comprehensive collection of nonlinear multivariate methods based on optimal scaling [12]. . The start point of underlying analysis is a 0/1 dummy matrix which is based on the data considered as categorical. As a result, a loss function which involving the unknown object and category scores is established. During the iterations analyzer squeeze the variables and calculates category scores that they are optimal in the sense of a minimal loss function. These procedures are referred to as optimal scaling full range of parameters either [13]. There are two types of aspect for optimal scaling: Correlational and Non-Correlational aspect.

In correlational aspect and optimization, simple example is correaltion matrix meaning there are only two variables. The variation of the correlation coefficient by choise of category quatification [14]. In general case, there are multi variables not only two those lead diverse analysis forms: sum of correlations, sum of absolute correlations, eigenvalue aspect, determinal aspect, squared multiple correlations, and sum of squared multiple correlations [13]. In Non-correlational aspect, meaning linearizing regressions, the bilinearizability is core issue. Bilinearizability means that we can find transformations of the variables such that all bivariate regressions are exactly linear [13].

3. RESEARCH METHODOLOGY

3.1 Data Join and Cleansing

This study uses three years weather data since 2010 by the Korea Meteorological Administration (KMA) an hour diced and the same period occupational injury dataset from the Korea Occupational Safety and Health Agency (KOSHA). In order to join two different types of dataset setting primary key for database is core. The common and only factor of two different source dataset is region: the weather observation spot coordinates, and occupational injury accident spot in occupational injury report.

Before join two dataset, modification of regional data was necessary because the region data of KMA's is coordinate and KOSHA's is administrational address where the address regulation has been changed twice. Therefore, modifying regional data to match each of dataset is essential. In this research, I modified and matched them by four steps. First, I modified all old fashioned KOSHA's address data to new address regulation by text divide work with the Korean postal service address history data. Second, transform administrational address data at first step to coordinate data via weather spot address dataset of KMA. Third, calculate the nearest weather observation spot coordinate from occupational injury report address. Last, marked unique number according to coordinate data at each dataset. Figure 5 shows the process of primary key generation.

There are 107 missing (unknown) variables for the primary key generated because of fault of KOSHA dataset address which is irregular manual input data such as mistyping and not full address. Those 107 missing variables are manually filled. In this study we transfer spot number to minimum legal region size 'Dong' and mark post code for them. There are also multiple spots in same region because of height of instrument and other factors. Since purpose of this study is find out relation between weather factors and occupational injury, we choose the closer spot to downtown or lower height. Those kind of works could not avoid manual works because observation spot has own characteristic and purpose.

Figure 5 shows the brief process of primary key generation without manual several works. The process basically includes data format related works such as transforming character field to numeric for matching.

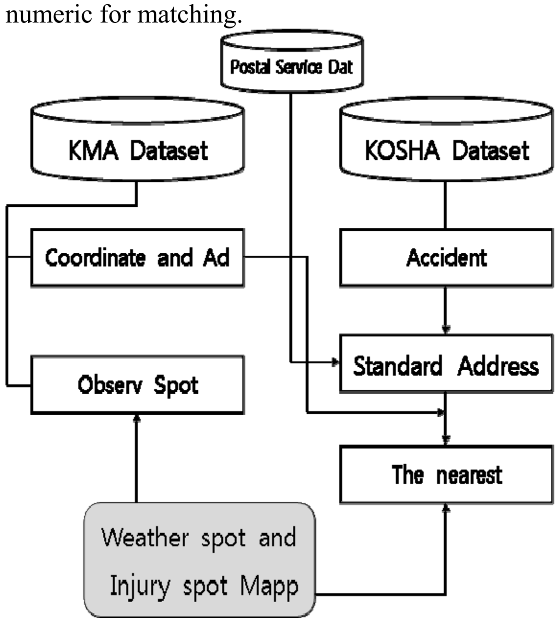

Figure 5: Dataset Join Primary Key Generation Process

After mapping regional spot, time mapping is performed. The KMA weather dataset has separate date format field and text based hour term time field 'hour(numeric)+h(character)' and KOSHA dataset has one field having date and specific time. In that, the KOSHA time field should be divided to date and time that transformed to KMA format. Firstly, date and time is divided by simple database function 'left' and time is transformed by below rule. In the notation, t(m) stands for minutes of KMA format time while t(h) is hour. The final primary key made for this research is combination of spotnumber in figure 5 and h in below notation and final dataset consist of 197,382 records.

IF t(m) > 30 THEN h=t(h)+1 ELSE h=t(h) (1)

Although KMA weather data and KOSHA occupational injury dataset is joined, there are massive cleansing works remains especially for KOSHA dataset because KOSHA injury reporting system input interface has lots of informal factors meaning those are not standardized or have been changed. For example, some of injury cause has multi-choice such as falling and slip, and some of them are not formal select input, but free text form.

Figure 6 shows informal dataset of injury data, and to standardize the dataset, decision of analysis purpose field is necessary. Since the purpose of this research is to make 'safety weather index', I clarify necessary fields such as time and type of injury.

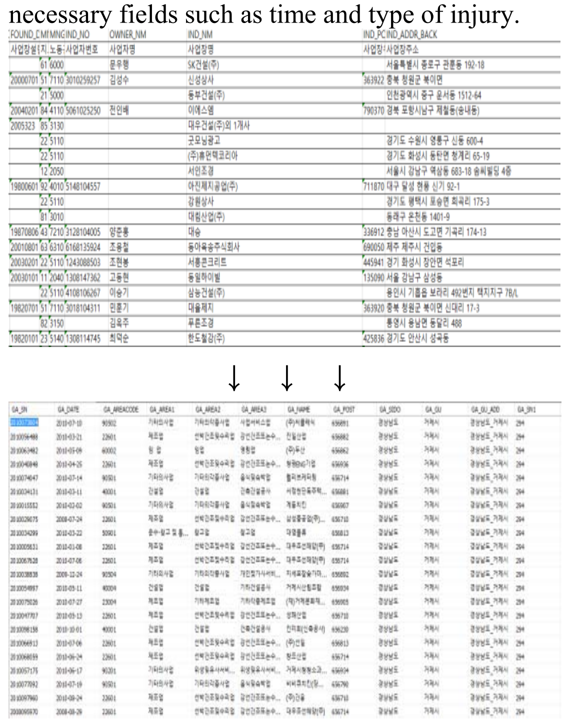

Figure 6: Informal Dataset is cleaned and joined to formal

Since the weather measurement spot is not directly accurate to regional section of Korea, transfer measurement instrument spot to regional data is firstly performed. In this study we transfer spot number to minimum legal region size 'Dong' and mark post code for them.

There are also multiple spots in same region because of height of instrument and other factors. Since purpose of this study is find out relation between weather factors and industrial injury, we choose the closer spot to downtown or lower height. Final dataset consist of 518,208 records.

3.2 Correlation and Optimal Scaling

Weather factors utilized for this research are five: temperature, humidity, wind speed, rain amount, and snow amount. The correlation among weather factors and cause of injury factors are analyzed by Pearson correlation. Before correlation analysis, for the further study I tried multi logistic regression for causality analysis.

For correlation analysis with five weather factors and injury accident, target injury accident type is chosen by their frequency. In this research I choose three major accident: drop(15.1%), stuck(17.1%), and trip(18.7%). These three injury accidents are over 50% of occupational injury reason in construction industry and supposed to related to weather condition.

4. ANALYSIS RESULT

4.1 Basic data analysis

Table 4 show major frequency of accident from dataset I utilize for this research. Although there are diverse accident factors not listed on table 4 such as drawn, animal attack, violence, and suffocation, those are not analyzed because of their small sample size. In this research, I utilize top three portion accident type.

However, there are still diverse factors to be analyzed such as hit by object, cut, and bump. In occupational injury research, in fact, every accident type is important because those are directly or indirectly related to employee's life: life not only in terms of live or dead but also their remaining life because those kind of injury usually lead physical body disable.

TABLE 4: FREQUENCY OF MAJOR ACCIDENT TYPE IN CONSTRUCTION INDUSTRY

Accident Type	Frequency	Portion
Inside Traffic accident	614	0.1%
Chemical Poison	2,056	0.4%
Explosion	2,078	0.4%
Fire	2,177	0.4%
Electric Shock	2,288	0.4%
Collapse	2,660	0.5%
Pin	14,154	2.7%
Outside traffic accident	22,691	4.4%
Work related disease	32,069	6.2%
Bump	40,232	7.8%
Cut	43,406	8.4%
Hit by object	44,311	8.6%
Drop	78,195	15,1%
Stuck	88,429	17.1%
Trip	96,761	18.7%

When it comes to monthly data, almost all months have trip as the highest rank except April, May, and July. In those months, stuck accident type get the highest frequency rank those phenomenon could be told that there are weather factors. However, one can find in this research, there are not simple causality between weather factors and occupational injury meaning not there are no' causality but not 'simple' causality that I found in this research. There could be causality for further research such as pattern analysis and so on. Simple causality test shows at logistic regressions below.

4.2 Logistic Regression

In order to analyse causality, several logistic regression is performed. As a result there are not considerable direct causality between weather factors and occupational injury, but it is just simple analysis result for further studies not a purpose of this research. Table 5 shows binomial logistic regression result. In binomial logistic, dependent variable is accident happened or not.

TABLE 5: BINOMIAL LOGISTIC REGRESSION

`	-2log likelihood	Cox and snell R square	Nagelkerke R Square
Temp	3285968	.005	.011
Hmd	3285968	.005	.011
W.S	3290624	.005	.009
Rain	3313045	.000	.000
Snow	3313043	.000	.000

Besides the binomial logistic regression, multi logistic and other regression test shows there are not direct causal relationship between weather and accident. Table 6 shows R-square of multi logistic regression which also has very weak causality between weather and occupational accident. Above all negative result about casual relationships, however, it does only means weather factors directly causes occupational accident not means there are not any relationship between them. Related research also shows there are not simple direct causal relationship between them [17]. It does mean there are complex causal relation between weather and accident.

TABLE 6: MULTI LOGISTIC REGRESSION

Pseudo R-Square	
Cox and Snell	.034

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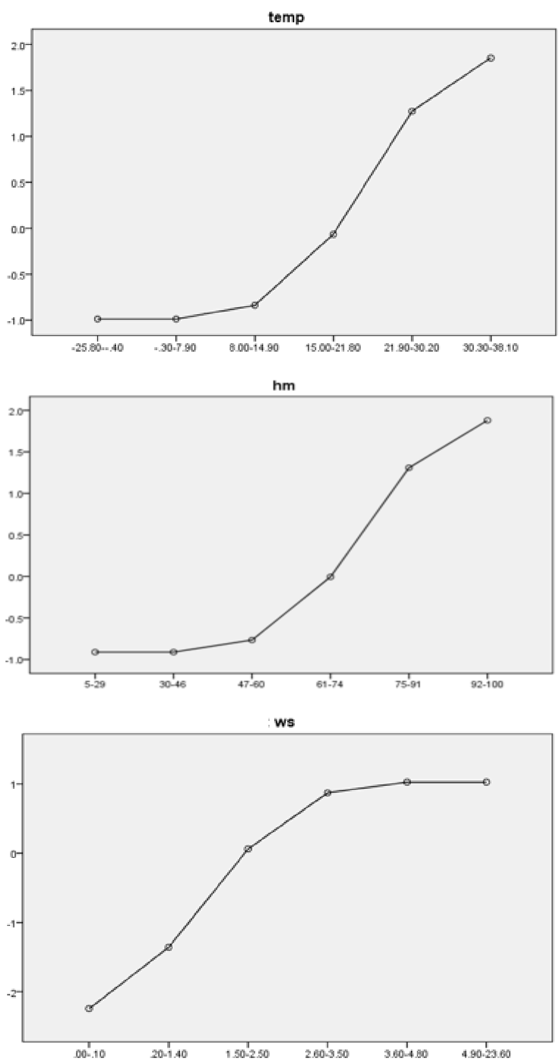
Nagelkerke	.069
McFadden	.051

4.3 Optimal Scaling

Figure 7 shows result of optimal scaling for with seven degree for temperature, humidity, and wind speed those have enough observation numbers. Rain and snow amount has not seven degree because of observation frequency meaning in rainy and snow day, construction is usually stopped.



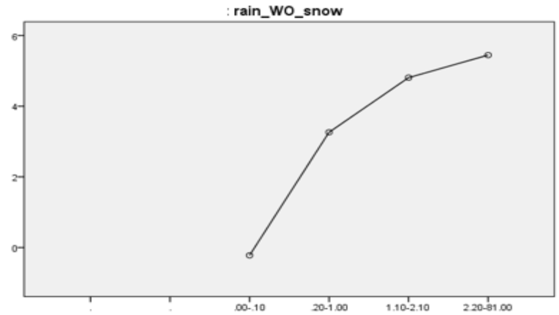


Figure 7: Optimal Scaling Result

As one can see at figure 7, for each weather factors, it has significant linear or non-linear trend line by scale. However, when it comes to the each accident divided dataset, the correlation result is different, meaning for each accident factor, there are different weather factors having correlation.

Table 7 shows weather factors having correlation for occupational accident type. Drop(Falling) has four weather factors having correlations, while trip and bump have three weather factors. Almost all accident type has not correlation to amount of snow weather factor. Although there could be diverse reason for snow amount exception, I expect in Korea, winter with snow day barely have construction work because of safety and other labor related issue such as labor law. Stuck type has only two weather factors having correlation: temperature and wind speed.

TABLE 7: INJURIES CORRELATION WEATHER FACTOR

Accident Type	Correlation Weather Factors
Drop	Temperature, Humidity, Wind Speed, Rain
Stuck	Temperature, Wind Speed
Trip	Temperature, Humidity, Wind Speed
Bump	Temperature, Humidity, Wind Speed

TABLE 8: SAFETY WEATHER INDEX FOR STUCK

Grade and InjuryType		G1	G2	G3	G4	G5	G6	G7
STUCK	Temp							
	TEMP	-24.1~-2.2	-2.1~5.5	5.6~11.8	11.9~17.7	17.8~24.0	24.1~31.7	31.8~37.5
	TEMP(Freq)	5,079	13,008	12,961	11,671	17,447	17,791	1,055
	InjuryRate	2.60%	2.50%	2.73%	2.60%	2.63%	2.93%	3.05%

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	Wind Speed							
	WS	0-1.1	1.2~2.1	2.2~3.0	3.1~4.0	4.1~5.2	5.3~23.6	-
	WS(Freq)	15,299	20,306	16,761	13,239	8,159	5,248	-
	Injury Rate	2.16%	2.71%	3.05%	3.09%	2.93%	2.27%	-

Table 8 shows sample safety weather index for stuck injury accident. For comfort, grades are named G1 to G7, but numbers on grade does not mean it's injury rate is higher or lower. In stuck case, temperate G3, G6, and G7 has high accident rate then others while wind speed G3,4 and 5 has. However, when it comes to the frequency, temperate grade 2, 5, and 6 has the highest injury frequency. This index reflect construction work frequency on those temperature. In Korea, those temperatures are spring or autumn those season have very high density of construction. In that, application of index should be consider both frequency and accident rate.

5. CONCLUSION

In this research, whole three years weather dataset and occupational injury dataset is merged to analyze by coordinate of weather observation point and hour unit time. Five weather factors are utilized for analysis and representative three injury factors are also analyzed. Data cleaning and merging methodologies are complicate because of different data source and standard they have.

In causal relation analysis, there are not simple significant causality found in this research. However, causal relation analysis is not for main purpose of this research and simply analyzed for future research. Through correlation analysis and optimal scaling, I found significant correlation between weather factors and injury accident reason, and through the optimal scaling for each injury type, this research suggests safety weather index for construction industry. Grades number in the index does not mean degree of injury warning rate and both frequency and injury rate for each grade should be considered for safety.

6. LIMITATION AND FUTURE RESEARCH

Although this research suggests methodology to make database based safety weather index, there are limitations and need further research. Firstly, the dataset in this research could not distinguish that there was a construction or not. That means injury rate is affected. Secondly, causal relation analysis is simply performed because of this research main purpose: safety index. In that, in further research, more detail causality research could make significant result to prevent occupational injuries. On third, optimal scaling grade is targeted to seven, for detail and those specific target grade could lead different index result.

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