Reasonability of Determination Equations for Assignment of Safety Engineers to Construction Sites

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Abstract
Three hundred questionnaires, which were created based on the subjective feedback from field safety engineers, were distributed nationwide to those in the construction field. The purpose of this was to receive feedback regarding current issues in the field. The questionnaire was reviewed by an advisory committee before being sent to safety management section chiefs at the top 100 construction companies, the goal of which was to ensure a high level of respondents.

The grades and numbers of safety engineers who have to be assigned to construction sites are determined statistically based on the project cost for each type of project as well as the risk level of each type.

1) Through a review of the existing assignment system, it was found that experienced safety engineers should be assigned to construction sites. If more experienced engineers are assigned, it will lessen the possibility of accidents.

2) The determination equation for selecting safety engineers for apartment construction projects was verified to be very effective. A comparison was made with the German equation using risk level so as to allow reasonable assignments of safety engineers to be made according to the project characteristics.

Keywords: formal questionnaire survey; full-time worker; project amount; safety engineer assignment

1. Introduction
The standard for the assignment of safety engineers at construction sites states that the primary construction contractor must make these decisions. The problem lies in the fact that little or no consideration is given to the project size and/or to hazardous work conditions, but rather almost solely to personnel requirements.

In response to this, it has been suggested that countermeasures (with respect to the number and size of projects) should be implemented in order to improve the performance of safety engineers.

Prior to discussing this, current issues relating to individual job performance must be pointed out.

(1) Individual incompetence
In general, safety engineers, possessing only related certificates, do only what they are told to do without prior knowledge and expertise related to the task. Subsequently, personal dissatisfaction often leads to premature cessation of their involvement in the project.

(2) Employment problems & atmosphere
Construction companies and most on-site construction management want safety engineers to work at both their head office and the job sites, or with both the management department and the job site simultaneously.

Field superintendents would rather use their safety management budget for other purposes. This creates safety risks for safety engineers.

Subcontracts are awarded through the "lowest bidder awarding" system, which ultimately trivializes the function of the management supervisor somewhat.

Additionally, the primary contractor tends to recruit those safety engineers with little experience by offering a low salary.

Finally, safety engineers' evaluations are not considered by the main contractor during his/her evaluations of the subcontractors.

2. Method
In this study, the authors reviewed the results of related Korean documents, international records, and any preceding studies. Prior to continuing, they addressed potential problems related to this study, as well as the proper course of action for the study.

Data related to the general information from the respondents, such as the number of years of experience

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they have, the contract award grade of the company (company size), and their work location in Korea were initially gathered.

Whether they were required safety engineers according to the project amount, and information pertaining to their safety engineer qualification class by risk grade was also sought.

Three hundred questionnaires created based on the subjective feedback from field safety engineers were distributed nationwide to those in the construction field. The purpose of this was to receive feedback regarding current issues in the field. The questionnaire was reviewed by an advisory committee before being sent to safety management section chiefs at the top 100 construction companies, the goal of which was to ensure a high level of respondents.

To recap, a total of 400 questionnaires were distributed nationwide, both by fax and by email, to those in the construction field. The Korean Ministry of Labor assisted in this effort, sending the questionnaire to the Korean construction companies rated from 101st to 200th.

2.1 Study method

Reviewed data and materials, as shown in Table 1., were discussed by safety experts who worked as section chiefs in the safety management departments of the top 30 construction companies. The purpose of this was to ensure that the authors' results would be more field-oriented.

Prior to the dissemination of the questionnaire, an advance preliminary survey was created and delivered to 10 construction companies, including D, K, M, SY, P, H, and DB. Subsequently, 33 completed surveys were collected. The information collected from these surveys served as the basis from which the authors' main questionnaire was created.

The advance survey was the first part of the main questionnaire and was created with the support of an advisory group. After collecting information through direct interviews, these surveys were distributed nationwide. Correlations among the items on the questionnaire were statistically reviewed to determine which items were to be selected for the second survey. Therefore, the results from the first survey were reviewed and analyzed statistically for significance level and correlations (R-square).

2.2 Review of advanced study result

It is mandatory for contractors to assign field safety engineers to construction sites. However, construction contractors often choose low-level engineers in order to cut labor costs. As a result, these engineers are unable to perform their duties independently and objectively.

Additionally, the assigning of safety engineers is not usually done according to project size or the level of project risk because existing requirements specify that a safety engineer's qualifications are sufficient for an assignment (i.e., not their experience).

All concerned parties, including the employer, should take part in establishing a safety management system. In doing so, a framework of responsibility and duty will result.1

In previous research234, half of the employers were well aware of their assumed role and responsibility in relation to field accidents or incidents. The level of awareness increased in those employers who were government authorities.

Safety must be considered at all stages of activity within the construction industry, whether it be in the design and planning stages, the selection of construction materials and techniques, or the determination of construction schedules. Therefore, supervisors and designers, as well as employers, should actively participate in this process to ensure field safety. In addition, they should assume responsibility and proper roles for reestablishing the employer's position.

Table 1. Status of Construction-related Deaths and Injuries During the Period, 2005-2007

| Type       | Construction Company | 2007 | 2006 | 2005 |
|------------|----------------------|------|------|------|
|            |                      | Weighted Factor | Non-weighted Factor | Weighted Factor | Non-weighted Factor | Weighted Factor | Non-weighted Factor |
| Employee Deaths |                      | 0.50 | 3.38 | 3.48 | 0.26 | 4.87 | 3.81 |
|            |                      | 0.0 | 1.8 | 0.42 | 1.7 | 2.76 | 1.85 |
|            |                      | 0.4 | 0.26 | 0.4 | 0.24 | 1.41 | 0.02 |
|            |                      | 0.08 | 2.1 | 0.4 | 0.24 | 4.28 | 0.27 |
|            |                      | 1.85 | 3.249 | 0.4 | 0.24 | 40.027 | 0.7 |
|            |                      | 0.25 | 4.33 | 0.27 | 0.24 | 50.52 | 3.7 |
| Employee Injuries |                      | 29.65 | 50.14 | 25.78 | 36.93 | 37.78 | 35.20 |
| Exchange Accident Rate (%) |          | 0.12 | 4.58 | 0.12 | 0.06 | 41.387 | 0.18 |
|            |                      | 0.21 | 50.14 | 0.18 | 0.19 | 50.14 | 0.19 |
|            |                      | 0.06 | 50.14 | 0.18 | 0.19 | 50.52 | 0.13 |

* Annual accident rate from the statistics of the Ministry of Labor, Korea.

* When calculating the exchange rate of construction companies, ten times the weight factor should be given to death cases.
2.3 Calculation of the working hours for a German construction safety engineer

The formula created in this study should be verified regarding its practicality.

The German risk grade classified according to the task was applied to calculate the working hours of safety engineers who should be assigned to construction sites. The employer can estimate how many days a safety engineer should be assigned per year using Tables 2. and 3.

A road and building construction project was used as a sample case of a typical civil and building project.

(1) Case 1

1. How many hours should a safety engineer be assigned in the case of a road construction project with 150 full-time workers?

2. Calculation

   Risk grade 7.3 (German risk grade classification table), first group.

   100 workers \times 3 \text{ hours} = 300 \text{ hours/year}
   50 workers \times 2.25 \text{ hours} = 113 \text{ hours/year}

The total for this safety engineer should be 413 working hours/year

| Type          | Risk grade | Number of laborers (person) | Working hours for a safety engineer (hours/year·person) |
|---------------|------------|-----------------------------|--------------------------------------------------------|
| First group   | Up to 8.5  | 1-100                       | 3                                                      |
|               |            | 101-200                     | 2.25                                                   |
|               |            | 201-500                     | 1.25                                                   |
|               |            | More than every 500         | Added 1.25                                             |
| Second group  | More less  | 1-100                       | 4                                                      |
|               | 8.5        | 101-200                     | 2                                                      |
|               |            | 201-500                     | 2.25                                                   |
|               |            | More than every 500         | Added 1.50                                             |

(1) Case 2

1. How many hours should a safety engineer be assigned in the case of a building construction project?

2. Calculation

   Risk grade 16.1, (German grade level classification table), second group

   100 workers \times 4 \text{ hours} = 400 \text{ hours/year}
   100 workers \times 3 \text{ hours} = 300 \text{ hours/year}
   300 workers \times 2.25 \text{ hours} = 675 \text{ hours/year}
   500 workers \times 1.5 \text{ hours} = 750 \text{ hours/year}

The total for this safety engineer should be 2,125 working hours/year

3. Result

3.1 Preliminary survey

3.1.1 Result of the preliminary survey

The results of the preliminary survey are shown in Table 4.

Table 4. Results Related to the Distribution of and Response to the Preliminary Survey

| Company Name | Number Distributed | Number of Replies | Response Rate (%) |
|--------------|--------------------|-------------------|-------------------|
| S1           | 20                 | 4                 | 20.0%             |
| S2           | 20                 | 5                 | 25.0%             |
| S3           | 20                 | 3                 | 15.0%             |
| S4           | 20                 | 4                 | 20.0%             |
| S5           | 20                 | 1                 | 5.0%              |
| S6           | 20                 | 4                 | 20.0%             |
| S7           | 20                 | 4                 | 20.0%             |
| S8           | 20                 | 3                 | 15.0%             |
| S9           | 20                 | 2                 | 10.0%             |
| S10          | 20                 | 3                 | 15.0%             |
| Total        | 200                | 33                | 16.5%             |

A total of 33 questionnaires with 159 responses were collected after distributing 400 questionnaires to ten (10) construction companies.

3.2 Main survey

The main survey was conducted on two accounts by distributing 750 questionnaires to six metropolitan cities via mail, fax, or email. The authors predicted that 110 to 150 would be collected, giving a 15 to 20 percent recovery rate.

The responses of those safety engineers with more than five years' employment experience were particularly noted. This "five year" experience included having completed at least one apartment building or tunnel project.

The feasibility of the questionnaire items was reviewed by experienced division chiefs from the safety management departments at the top thirty construction companies. This was done as a control group in order to reduce the standard deviation. It was

Table 3. German Risk Grade Classification

| Reference code | Type of Work                              | Risk grade |
|----------------|-------------------------------------------|------------|
| 100            | Structural work for civil and building    | 16.1       |
| 200            | Extension work                            | 7.3        |
| 210            | Cutting and grinding natural and artificial stone | 7.8 |
| 220            | Manufacturing fabrication part and concrete product | 8.5 |
| 230            | Cleaning chimney                          | 5.3        |
| 300            | Road construction work                    | 7.3        |
| 310            | Cable-installation work                   | 5.1        |
| 320            | Channel and pipeline installation work    | 9.4        |
| 330            | Tunneling work                            | 27.3       |
| 340            | Waterline – installation work             | 18.7       |
| 350            | Special civil work                        | 12.8       |
| 360            | Electrical distribution work              | 12.5       |
| 400            | Cleaning roads and buildings              | 4.5        |
| 500            | Dismantling, waste-disposal and blasting work | 27.3 |
| 600            | Naval architecture work                   | 11.9       |
| 700            | Construction work not related to the work method, task by task | 44.7 |
| 800            | Insurance for self business administration | 5.0 |
| 900            | Office area in the construction work area | 1.0 |
deemed that this advance process was more important than the general statistical trend.

3.2.1 Main second survey
Because the second phase of the survey contained a number of questions for safety engineers with moderate to high levels of experience, those with five or fewer years of experience were excluded from the statistics that are compiled in Table 5.

3.2.2 Second survey results
(1) Apartment building work
Apartment buildings are one of the most common construction projects nation-wide in Korea in the category of housing projects and architectural work. The grade of safety engineers from one (1) to four (4), consisting of basic, intermediate, advanced and special grade, are classified in the Korean grade system. The number of safety engineers is calculated using a formula which was created from a study shown in Table 6. This data is also shown graphically in Figs.1. and 2.

(2) Road construction work
Road construction work is also one of the most typical of construction projects carried out nation-wide in Korea in the civil project category. The grade of safety engineers from one (1) to four (4), consisting of basic, intermediate, advanced and special grade, are classified in the Korean grade system. The number of safety engineers is calculated using a formula created for road construction work in this study, as shown in Table 7. This data is also shown graphically in Figs.3. and 4.

3.3 Determination of the grade/numbers according to the project type and cost
As in the above result, the number of safety engineers who should be assigned to each site varies with the project cost. Some regression analyses were run to gain a deeper understanding of the data.

3.3.1 Determination of the equation for the grade and number of safety engineers required in terms of the project cost
Regression analysis was conducted using the project cost as the independent variable (X) and the grade as the dependent variable (Y).

1) Equation for the required number of safety engineers as determined by the project cost
Regression Analysis: Required Number versus Cost
The regression equation is
Required Number = 1.652 + 0.000892 cost
S = 0.508665  R-Sq = 91.9%  R-Sq(adj) = 90.9%

Table 6. The Number of Safety Engineers Assigned to Apartment Building Projects as Determined by the Project Cost and Grade
(Amount unit: Korean eok won)

| Project Cost  | Grade | Number of Safety Engineers |
|--------------|-------|-----------------------------|
| 100 or less  | 1.18  | 1.03                        |
| 100 - 500    | 1.73  | 1.65                        |
| More than 500 - less than 1000 | 2.07 | 2.10                        |
| 1000 - 1500  | 2.45  | 2.89                        |
| More than 1500 - less than 2000 | 2.66 | 3.63                        |
| 2000 - 2500  | 2.84  | 4.28                        |
| 2500 - 3000  | 3.01  | 4.68                        |
| More than 3000 - less than 4000 | 3.28 | 5.05                        |
| 4000 - 5000  | 3.34  | 5.32                        |
| More than 5000 - less than 6000 | 3.54 | 5.85                        |

*Korean eok won = 100,000,000 won = 0.1 billion won
ex) 100 = 10,000,000,000 Korean won
*1USD = 1000 Korean won

Table 7. The Number of Safety Engineers Assigned to Road Construction Projects as Determined by the Project Cost and Grade
(Amount unit: Korean eok won)

| Project Amount  | Grade | Number of Safety Engineers |
|-----------------|-------|-----------------------------|
| 100 or less     | 1.27  | 1.11                        |
| 100 - 500       | 1.42  | 1.34                        |
| More than 500 - less than 1000 | 1.66 | 1.57                        |
| 1000 - 1500     | 1.93  | 1.78                        |
| More than 1500 - less than 2000 | 2.18 | 2.12                        |
| 2000 - 2500     | 2.41  | 2.36                        |
| 2500 - 3000     | 2.64  | 2.52                        |
| More than 3000 - less than 4000 | 2.79 | 2.94                        |
| 4000 - 5000     | 3.15  | 3.28                        |
| More than 5000  | 3.27  | 3.53                        |

*Korean eok won = 100,000,000 won = 0.1 billion won
ex) 100 = 10,000,000,000 Korean won
*1USD = 1000 Korean won
Analysis of Variance

| Source     | DF | SS     | MS    | F     | P     |
|------------|----|--------|-------|-------|-------|
| Regression | 1  | 23.5264| 23.5264| 90.93 | 0.000 |
| Error      | 8  | 2.0699 | 0.2587|       |       |
| Total      | 9  | 25.5964|       |       |       |

Fig.1. The Required Number of Safety Engineers as Determined by the Project Cost for Apartment Building Projects

A regression equation, $y = 0.000892x + 1.652$ for the apartment building project was produced to estimate the number of safety engineers who should be assigned to each project according to the project cost, with this being $600,000,000,000$ Korean won ($= 6000$ Korean eok won $= 600$ billion Korean won $= USD 0.6$ billion, $1USD = 1000$ Korean won) or less. It is considered that the result is significant statistically.

2) Equation for the safety engineer’s grade as determined by the project cost

Regression Analysis: Grade versus Cost
The regression equation is

Grade = 1.731 + 0.000389 cost

$S = 0.300028$  R-Sq = 86.1%  R-Sq(adj) = 84.4%

Analysis of Variance

| Source     | DF | SS     | MS    | F     | P     |
|------------|----|--------|-------|-------|-------|
| Regression | 1  | 4.47847| 4.47847| 49.75 | 0.000 |
| Error      | 8  | 0.72013| 0.09002|       |       |
| Total      | 9  | 5.19860|       |       |       |

A regression equation, $y = 0.000389x + 1.731$ for an apartment building was projected to estimate the number of safety engineers who should be assigned to each project according to project cost, this being $600,000,000,000$ Korean won ($= 6000$ Korean eok won $= 600$ billion Korean won $= USD 0.6$ billion, $1USD = 1000$ Korean won) or less. It is considered that the result is significant statistically.

Fig.2. The Grade of Safety Engineers as Determined by Project Cost for Apartment Building Projects

Regression Analysis: required number versus cost
The regression equation is

Required Number = 1.238 + 0.000450 cost

$S = 0.110112$  R-Sq = 98.4%  R-Sq(adj) = 98.2%

Analysis of Variance

| Source     | DF | SS     | MS    | F     | P     |
|------------|----|--------|-------|-------|-------|
| Regression | 1  | 5.99105| 5.99105| 494.12| 0.000 |
| Error      | 8  | 0.09700| 0.01212|       |       |
| Total      | 9  | 6.08805|       |       |       |

Fig.3. The Required Number of Safety Engineers as Determined by the Project Cost for Road Construction Projects

A regression equation, $y = 0.00045x + 1.238$ for road construction work was produced to estimate the number of safety engineers who should be assigned to each project according to the project cost, with this being $600,000,000,000$ Korean won ($= 6000$ Korean eok won $= 600$ billion Korean won $= USD 0.6$ billion, $1USD = 1000$ Korean won) or less. It is considered that the result is significant statistically.

2) Equation for the safety engineer’s grade as determined by project cost

Regression Analysis: Grade versus Cost
The regression equation is

Grade = 1.415 + 0.000379 Cost

$S = 0.142219$  R-Sq = 96.3%  R-Sq(adj) = 95.9%
Table 1: Analysis of Variance

| Source    | DF | SS     | MS     | F      | P     |
|-----------|----|--------|--------|--------|-------|
| Regression| 1  | 4.25775| 4.25775| 210.51 | 0.000 |
| Error     | 8  | 0.16181| 0.02023|        |       |
| Total     | 9  | 4.41956|        |        |       |

A regression equation, $y = 0.000379x + 1.415$ for road construction work was produced to estimate the grade of safety engineers who should be assigned to each project according to the project cost, with this being $600,000,000,000$ Korean won ($= 6000$ Korean eok won = $= 600$ billion Korean won = USD 0.6 billion, 1USD = 1000 Korean won) or less. It is thought that the result is significant statistically.

4. Verification of Formula Equations

4.1 Apartment building projects

As in section 3.2.2 above regarding the second survey results, two case studies were done after applying practical construction conditions using the formula created in this study.

Here, case 1 of a building project was applied using a practical condition to verify if the created formula is required.

- Required number = $1.238 + 0.00450$ cost
- Grade = $1.415 + 0.00379$ cost

5. Conclusion

Conclusions are summarized as follows:

1) The determination equation for selecting safety engineers for apartment construction projects has been verified to be very effective. A comparison has been made with the German equation using the risk level so that reasonable assignment of safety engineers can be made according to the project characteristics.

2) Quantitative and objective countermeasures can be established using these models when construction contractors create accident prevention plans in advance of their projects. This can only occur through improvement of company business administration and the enhancement of the safety engineer's position.

3) To determine the required number of safety engineers with respect to the risk level, models appropriate for different projects can be developed. However, the risk levels according to each type of work must be established by the government, as is currently the case in Germany. As further study, if a determination model with respect to the risk level can be effectively standardized, it can be introduced and implemented into the Korean construction industry. This is an especially relevant point given that the German system has been shown to be effective for Korea.

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