Application of modified extended method in CREAM for safety inspector in coal mines

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Abstract. Safety inspector often performs duties in circumstances contributes to the occurrence of human failures. Therefore, the paper aims at quantifying human failure probability (HFP) of safety inspector during the coal mine operation with cognitive reliability and error analysis method (CREAM). Whereas, some shortcomings of this approach that lacking considering the applicability of the common performance condition (CPC), and the subjective of evaluating CPC level which weaken the accuracy of the quantitative prediction results. A modified extended method in CREAM which is able to address these difficulties with a CPC framework table is proposed, and the proposed methodology is demonstrated by the virtue of a coal-mine accident example. The results are expected to be useful in predicting HFP of safety inspector and contribute to the enhancement of coal mine safety.

1. Introduction

In recent years, the one of considerable attention received from coal-mining industry is safety since it may contribute to the loss of human life and property and the situation of coal mine safety in China remains grim [1].

Among these accidents, the proportion of accidents caused by human failure is as high as 97.67%, and the proportion of accidents caused by manager behavioural error is 45.96% [2]. The safety inspector, as a grassroots-level manager, who is one of the most critical people, plays a role of “security guard” in coal mine operation. Therefore, the purpose of the paper reported here is to effectively prevent and reduce coal-mine accidents by quantifying the reliability of safety inspector during the coal mine operation.

Human reliability analysis (HRA) has been certified available for HFP (human failure probability) [3, 4], now it has developed three generations of different methods, and he second-generation methods focused on human cognition and context to address the limitations of error identification and probability estimation [5, 6, 7], such as CREAM.
During the coal mine operation, the duties performed by safety inspector really are affected by environment, technology, organization, task and individual factors that around the works [8]. Obviously, the reliability of safety inspector will be affected by the complex working condition. CREAM is a good method for quantifying human reliability with respect to working condition, and has been widely applied in various fields [9]. However, the shortcoming of lack of data, together with the difference of numerous fields, has weakened the application of well-established CREAM method. Therefore, a variety of studies upon modification of CREAM emerged. For instance, a modified basic method by providing the point estimation of HFP for PSA (Probabilistic Safety Assessment) is proposed [10]. Yang et al. [8] have proposed a modified CREAM approach to quantitatively estimate human reliability in marine engineering by establishing fuzzy IF–THEN rule on the basis of belief structures. Beford et al. [11] address the limitation of Basic method that the control mode intervals are too narrow to be consistent with the extended method by combining CPC weights with nominal probabilities. A new fuzzy CREAM methodology was developed by Ung [12] to overcoming the shortcoming of lack of sufficient failure data in CREAM by establishing multiple input-output rules. Akyuz et al. [13] present a modified Basic method in CREAM by using PII (Performance Influence Index) and CII (Context Influence Index) to acquire specific quantitative effects of CPCs to ascertain the control mode in crude oil tanker ships.

What the studies focus is the modification of the Basic method in CREAM which suffered from the limitation itself of failing to produce the probability of concrete action failure.

Hollande [14] gives the answer in extended method by developing the CPCs framework table. However, CPCs in CREAM are proposed based on the description of the situation with respect to nuclear power plant, and are characterized by linguistic expressions, which will lead to inapplicability and subjectivity when the approach is applied to other fields. Thus, it is necessary to develop a modified extended method in CREAM to address such problems. Some studies proposed the supplement of CPCs in the light of rail signals or gas networks [15,16]. Nevertheless, challenges for implementation of an effective CREAM method are still existed since the availability of CREAM in the coal mine domain is scarce. Therefore, a modified extended method in CREAM is provided to evaluate the reliability of safety inspector during the coal mine operation to enhance coal mine safety. A typical coal-mine accident is applied to the methodology to confirm the effectiveness. Section one in this paper express introduction, and section two deals with the proposed methodology upon reliability assessment in coal mine operation. The third section provides the CPCs framework table for safety inspector by analysing the factors affecting reliability and the evaluation model of CPCs upon the developed CPCs framework for safety inspector. The next two sections respectively conduct the demonstration of developed model and give discussion and conclusion with respect to coal mine safety.

2. Methodology description

As we know that, in traditional CREAM, CPCs are the crucial factor when assess human reliability. Therefore, it is essential to determine the reasonable CPCs level and weight when using CREAM to analyse human reliability. However, the nine CPCs are acquired with description of working condition in nuclear power plant, as well as described by linguistic expressions, which will lead to inapplicability and subjectivity when such approach is applied to other fields.

The modified extended method shown in Fig.1 develops CPCs framework table for safety inspector base on the outcome of factors affecting safety inspector reliability by analysing the duties that safety inspector performs. FCE (fuzzy comprehensive evaluation method) and AHP are utilized to determine each CPC’s level and weight respectively for avoiding inapplicability and subjectivity of CPCs. The modified extended method in CREAM considerably improves the coal mine safety by improving the accuracy of quantitative result of safety inspector reliability.
3. Quantification model
It is noted that safety inspector reliability considerably depends upon the reliability of his perception, cognition and decision-making. Therefore, on this stage, the factors affecting safety inspector perception, cognition, and decision making are first acquired with scenario analysis from five aspects i.e. environment, individual, organization, technology and task. Secondly, the work decomposition and analysis are taken into consideration to acquire the factors affecting safety inspector reliability. Once the factors affecting safety inspector reliability are determined, the quantification model of CPCs framework table and CPCs evaluation model can be established.

3.1. Construction of CPCs framework table
3.1.1. Analysis of factors affecting perception. Perception is a process that perceiving information from scenario. Firstly, the data that individual acquires from scenario is input into the individual brain cortex through a receptor, and then the useful information is output after a complex process in the cerebral cortex. Finally, cognition is realized based on the outcome of perception [17]. Sabah [18-19] reveals that perception is the primary factor driving individual’s intentions to do something.

The perception of safety inspector who is a common individual can be described as auditory sense, visual sense, olfactory sense, tactile sense, and static sense according to the definition of sensory organs [17]. Therefore, the factors affecting safety inspector perception (as listed in Table 1) are acquired through analysing factors affecting his auditory sense, visual sense, olfactory sense, tactile sense, and static sense according to the daily duties he performs base on the judgement from psychological expert.

Likewise, the factors affecting safety inspector cognition and decision-making are acquired as listed in Table 2 and Table 3.
**Table 1.** Factors affecting safety inspector perception.

| Individual factor | Intelligence; mental health; illness, drugs, and alcohol; physiological factors |
|-------------------|---------------------------------------------------------------------------------|
| Environment factor | Natural environment factor: Thunderstorm; changes in coal-mine seam thickness, concavity; softness and loose conditions of soil on the ground, etc.; mine pressure, water pressure, and ground temperature and pressure |
| Task environment factor | Lighting conditions; noise; rationality of space size and space layout; visibility; mine humidity and temperature |
| Technology factor | Equipment resource management: Equipment condition corresponding to the protective equipment installation; equipment condition relative to the use of facilities; equipment specifications |
| Man–machine interface of equipment | User-friendliness of man–machine interface |
| Quality and maintenance of equipment | Safety, reliability, and precision of the device; ability for error proofing, fault-tolerance, and error correction of equipment; equipment–maintenance condition |

**Table 2.** Factors affecting safety inspector cognition.

| Individual factor | Security responsibility, own safety technical quality, culture level, professional quality, and ability; self-protection ability, safety training and degree of safety knowledge to understand and master; emergency-disposal capacity, level of experience in dealing with emergency; familiarity with the working place and equipment and professional operation skill level |
|-------------------|---------------------------------------------------------------------------------|
| Organizational factor | Organizational safety culture: Rules and regulations of production safety; employee safety consciousness; continuous improvement strategy for safety culture; team harmony; organizational values and security management consciousness |
| Plan and procedure of organization | Perfect degrees or completeness of organizational process; rationality of organization plan; adjustment to organization plan; acceptability of plans and programs |
| Management process of organization | Specialized level of functional division of organization; division of duties and authorization of organization department; coordination ability of organization; organizational supervision system |
| Organizational education and training | Safety culture training; pre-service training; on-the-job training; emergency-measure training; support of professional training of personnel; evaluation of training process |
| Communication and feedback of organization | Communication and feedback in the department; communication and feedback among departments; Communication and feedback between the organization and outside world. |
| Organizational external aspect | Family factor; social factor |
Table 3. Factors affecting safety inspector decision making.

| Individual factor | Task factor | Organizational factor |
|-------------------|-------------|-----------------------|
| Gender and age; achievement motivation; physical fatigue and mental status; risk preference. | Complexity | Difficulty of task to be completed; aspect and content of checking and monitoring the work at the same time |
| | Urgency | Frequency of sudden events during operation |
| | Rationality | Man-machine allocation of work, Continuous working time and intensity |
| | Repeatability | Degree of task repeatability |

3.1.2. Analysis of factors affecting reliability. Factors affecting safety inspector reliability can be realized with task decomposition base on the outcome of factors affecting his perception, cognition and decision making.

There are total 12 functional items upon safety inspector’s duties or task during coal mine operation on the basis of “new coal mine safety training (after training) materials: coal mine safety inspector” proposed by Zhou [20], “conditions and functions of safety inspector in coal mine” of Law time [21] and “the responsibilities, rights and ethics of safety inspector in coal mine” published by Coal Mine Safety Production Network in China [22]. Here, the paper takes “functional item 9 and functional item 10” as examples for the analysis, as Fig. 2 shows. Similarly, the other functional items are analysed with the same method.

3.1.3. Development of CPCs framework table. With the outcome of above analysis, combining with the description of CPCs in CREAM, the CPC framework table for the safety inspector is realized, as listed in Table 4.

![Diagram](image)

Fig 2. Analysis of functional items 9 and functional 10.
3.2. Assessment of CPCs

It is in this step to establish the quantitative model by evaluating CPCs with fuzzy theory [23] on the basis of CPCs framework table for safety inspectors.

Here, the paper takes each CPC as study object, and develop quantitative model with FCE.

| CPC | Involved factor                                                                 | Sub factor                                                                 |
|-----|--------------------------------------------------------------------------------|---------------------------------------------------------------------------|
| Adequacy of organization (CPC1) | Organizational safety culture | Rules and regulations on production safety; safety consciousness; strategy of continuous improving safety culture; team harmony; consciousness of organizational values and security management |
| Management process of organization |  | Professional level of functional department of organization; assignment of responsibilities and extent of authorization in organization department; coordination ability of the organization; organizational supervision system |
| Communication and feedback of organization |  | Communication and feedback in the department; communication and feedback among departments; communication and feedback between the organization and outside world |
| Social aspect |  | Social economy and culture; social politics; system of social law |
| Working conditions (CPC2) | Natural environment | Weather/Thunderstorm; change in the coal-mine seam thickness, concavity and convexity; softness and looseness conditions of soil; mine pressure, water pressure, and ground temperature and pressure |
| Task environment |  | Lighting conditions; noise level; rationality of space and space layout; visibility; humidity and temperature |
| Adequacy of MMI and operational support (CPC3) | Equipment source management | Situation of protective equipment installation, facilities and equipment specifications |
| Availability of procedures/plans(CPC4) | Plan and program of organization operation | Completeness of organizational process; rationality of organization plan; adjustment to organization plan; acceptability of plans and programs |
| Time of day (circadian rhythm) (CPC5) |  | --- |
| Adequacy of training and experience (CPC6) | Personal preparation state | Responsibility upon safety, culture level, professional quality, and ability; self-protection ability, safety training and safety education; professional operation skill; emergency-disposal capability; familiarity with working place and equipment |
| Mental state |  | Safety consciousness, threat consciousness |
| Available time (CPC7) | Complexity of task | Difficulty of task to be completed; content of checking and monitoring work at the same time |
| Urgency of task |  | Frequency of sudden events during operation |
| Rationality of task |  | Balance of task assignment in the work; Time and strength of continuous working |
| Repeatability of task |  | Degree of task repeatability |
| Rationality of task |  | Man-machine assignment of work |
| Numbers of simultaneous goals (CPC8) | Management process of organization | assignment of responsibilities and extent of authorization in organization department; |
| Gender and age |  | Male/Female: 18–30 years old; male/female: 31–45 years old; male/female: 46-65 years old |
| Achievement motivation |  | Degree of achievement motivation preference (high achievement motivation, low achievement motivation) |
| Risk preference |  | Degree of risk preference (Risk avoidance, risk seeking, risk neutral) |
| Family aspect |  | Family relationship; environment; material condition of family life |
| Crew collaboration quality (CPC9) | Management process of organization | Division of duties and authorization of organization departments |
| Communication and feedback of organization |  | Communication and feedback in the department; Communication and feedback among departments; Communication and feedback between the organization and outside world |
| Personal preparation state |  | Safety, reliability, and precision of the device; self-protection ability, safety training; emergency-disposal capability; familiarity with working place and equipment, professional operation skill |
| Mental state |  | Safety consciousness, threat consciousness |
| Personal physical aspect |  | Intelligence; mental health; illness, drugs, alcohol; physiological factors |
3.2.1. Factor sets. In this section, the CPC1 of “Adequacy of organization”, which has four involved factors corresponding to some sub factors, is taken as the example for analysis.

The factor set of CPC1 can be expressed as follows:

\[ U = \{u_{11}, u_{12}, u_{13}, u_{14}, u_{21}, u_{22}, u_{23}, u_{24}, u_{31}, u_{32}, u_{33}, u_{41}, u_{42}, u_{43}\} = \{U_1, U_2, U_3, U_4\} \]

Where \( U_i \) is the \( i \)th “involved factor item” of the CPC1 and \( u_j \) is the \( j \)th “sub factor item” of \( U_i \).

3.2.2. Weight set. The paper regards the “involved factor” as “primary index factor” and their corresponding “sub factor” as “secondary index factor.” Weight set of CPC1 is defined with the relative importance of involved factors and sub factors and acquired using AHP. The weight set of the “primary index factor” can be expressed as follows:

\[ W = (\omega_1, \omega_2, \omega_3, \omega_4, \omega_5) \]

Where \( \omega_k (k = 1, 2, 3, 4) \) is the weight value of the “primary index factor”? Obviously, the weight value of CPC1 can be expressed as \( W = (\omega_1, \omega_2, \omega_3, \omega_4, \omega_5) \).

3.2.3. Fuzzy evaluation set. The fuzzy evaluation set of CPC1 is established according to the “level” and is expressed as follows:

\[ E = (e_1, e_2, e_3, e_4) = (\text{very effective}, \text{effective}, \text{ineffective}, \text{defective}) = (4, 3, 2, 1) \]

Where the score of “very effective” is 4, “effective” is 3, “ineffective” is 2, and “defective” is 1.

3.2.4. Evaluation of CPCs. The CPC1 is evaluated with the factor set, weight set and evaluation set. Firstly, there are N experts in coal mine domain are invited to give them evaluate scores for each “secondary index factor” according to their experience and knowledge with the evaluation set, and the scores are acquired using Eq. (1).

\[
S_{m,k} = (V_1, V_2, V_3, V_4) = \begin{bmatrix} e_1 & 0 & 0 & 0 \\ 0 & e_2 & 0 & 0 \\ 0 & 0 & e_3 & 0 \\ 0 & 0 & 0 & e_4 \end{bmatrix}
\] (1)

Where \( S_{m,k} (k = 1, 2, 3, 4; m = 1, 2, 3, 4, 5) \) represents each level score of the \( m \)th “secondary index factor” under the \( k \)th “primary index factor” and \( V_1, V_2, V_3, V_4 \) are the total votes on “very effective,” “effective,” “ineffective,” and “defective” of the “secondary index factor.” \( e_i (i = 1, 2, 3, 4) \) represents the score at each level.

Secondly, each membership degree level of the “secondary index factor” in evaluation set \( E \) is expressed as Eq. (2) shows.

\[
r_1 = \begin{bmatrix} S_{11} \\ N \\ S_{12} \\ N \\ \vdots \\ S_{1m} \\ N \end{bmatrix}; \quad r_2 = \begin{bmatrix} S_{21} \\ N \\ S_{22} \\ N \\ \vdots \\ S_{2m} \\ N \end{bmatrix}; \quad \vdots \quad r_e = \begin{bmatrix} S_{e1} \\ N \\ S_{e2} \\ N \\ \vdots \\ S_{em} \\ N \end{bmatrix}
\] (2)

Where \( \frac{S_{mn}}{N} \) is the membership of the \( m \)th “secondary index factor” under the \( k \)th “primary index factor”?
As known, evaluation of CPC1 is multifaceted problem which affected by various “involved factors” and “sub factors.” Hence, the paper chooses the weighted average fuzzy operator to evaluate CPC1. And, the fuzzy relationship matrix is established using Eq. (3) according to the weight set and Eq. (2).

\[
M_1 = W_1 \cdot \mathbf{r}_1 = [m_{11}, m_{12}, \ldots, m_{1n}], \quad M_2 = W_2 \cdot \mathbf{r}_2 = [m_{21}, m_{22}, \ldots, m_{2n}], \quad \ldots, \\
M_k = W_k \cdot \mathbf{r}_k = [m_{k1}, m_{k2}, \ldots, m_{kn}] \quad (3)
\]

Then

\[
M = [M_1, M_2, \ldots, M_k]^T, \quad B = W \cdot M = [b_1, b_2, \ldots, b_n]. \quad (4)
\]

Finally, the fuzzy comprehensive evaluation result vector \( B \) is developed. The weighted average principle [24, 25] is a better way to tackling the evaluate result vector \( B \). The relationship between \( A \) (A is a level value of the evaluation object) and \( B \) can be expressed by the following:

\[
A = \sum_{j=1}^{m} e_j b_j^K / \sum_{j=1}^{m} b_j^K, \quad (K \text{ is undetermined coefficient}) \quad (5)
\]

Where \( e_j \in E, b_j \in B \) and \( K = 1 \) [24]. When \( A \in [0.5, 1.5] \), the level of the CPC1 is “defective.” When \( A \in (1.5, 2.5] \), the level of the CPC1 is “ineffective.” When \( A \in (2.5, 3.5] \), the level of the CPC1 is “effective.” When \( A \in (3.5, 4.5] \), the level of the CPC1 is “very effective.” As it is seen in the analysis above, the weight value of CPC1 is realized, as well as its level. Likewise, the weight value and level of the other eight CPCs can be acquired.

4. Demonstration
In this section, proposed modified extended method in CREAM is demonstrated with a crucial safety inspector operation, which is excerpted from a coal-mine accident happened in 2005 [26].

4.1. Failure description
According to the report of coal-mine accident happened in 2005, the safety inspector failure upon inspection in this accident can be described as follows:

The maintenance and overhaul of the system in terms of gas monitoring what should be performed by safety inspector are not taken place, which resulted in failure of the gas-sensor underground. While the voice-alarm function failed to work for up to four months, which lead to the absence of sound alarm on the day accident happened.

4.2. Identify CPCs
In this section, the author invited four experts in coal mine domain to give their scores upon sub factors and the scores can be seen in Table 5.
Table 5. Statistical table of the CPC factors and their scores.

| CPC                      | Involved fact or item                      | Sub factor item and evaluation of experts | Total score | Level |
|-------------------------|-------------------------------------------|------------------------------------------|-------------|-------|
| Adequacy of MMI and operational support (CPC1) | Equipment resource management             | Situation of provision of corresponding equipment and protective equipment. 2/2/2/2 | 8           |       |
|                         |                                           | Situation of providing and using the facilities. 2/2/1/1 | 6           |       |
|                         |                                           | Equipment specifications. 1/2/2/2         | 7           | E=(e₁, e₂, e₃) |
|                         | Man–machine interface                     | User-friendliness of the man–machine interface. 2/2/1/2 | 7           | E=(e₁, e₂, e₃) |
|                         | Quality and maintenance of equipment      | Safety, reliability, and precision of the device itself. 1/1/1/1 | 4           | 4,3,2,1 |
|                         |                                           | Ability of error-proofing, fault-tolerance, and error correction of equipment. 1/1/2/1 | 5           | 4,3,2,1 |
|                         |                                           | Equipment maintenance condition. 1/1/1/1 | 4           |       |
| Available time (CPC2)  | Complexity of task                        | Difficulty of task to be completed. 3/3/2/3 | 11          |       |
|                         |                                           | Aspect and content of checking and monitoring in work at the same time. 2/2/1/2 | 7           | E=(e₁, e₂, e₃) |
|                         | Urgency of task                           | Frequency of sudden events happening during operation. 2/2/2/2 | 8           | E=(e₁, e₂, e₃) |
|                         | Rationality of task                       | Balance of task allocation in the work. 3/3/2/2 | 10          |       |
|                         |                                           | Time and strength of continuous working. 3/3/2/2 | 11          |       |
|                         | Repeatability of task                     | Degree of task repeatability. 3/3/3/3 | 12          |       |
| Availability of procedures/plans (CPC3) | Plan and program of organizational operation | Perfect degrees or completeness of organizational process. 1/1/2/1 | 5           |       |
|                         |                                           | Rationality of organization plan. 1/1/1/1 | 4           |     |
|                         |                                           | Adjustment to organization plan. 2/1/2/1 | 6           |     |
|                         |                                           | Acceptability of plans and programs. 1/1/2/1 | 5           |     |

4.3. Assess CPCs
The results are listed in Table 6 (here, the expected effects on performance reliability of CPCs corresponds to “not significant” is not taken into consideration, since it is impossible to predict the effect will be positive or negative).
Table 6. Evaluation results of CPC1.

| Cognitive activity | CPC | Evaluation | Weight | Level | Expected effect on performance reliability |
|--------------------|-----|------------|--------|-------|---------------------------------------------|
| Maintain           |     | Adequacy of MMI and operational support | Monitoring and control system was not reasonable; voice-alarm function failure | 3.3170 | inappropriate | reduced |
| Available time     |     | Failure for up to four months | | 2.5687 | adequate | improved |
| Availability of procedures/plans | | Lack of maintenance plan/program | | 2.6106 | inappropriate | reduced |

4.4. Analyse reliability
According to the results shown in Table 7, and the cognitive activities and cognitive function table (C A&CF) in CREAM [14], the cognitive function, cognitive-function failure mode, and corresponding basic cognitive failure probability values ($C_{FP_{bi}}$) upon safety inspector in this accident, which are listed in Table 7, are acquired.

Table 7. Basic values of the cognitive failure probability.

| Cognitive activity | Cognitive function | Error mode | $C_{FP_{bi}}$ | CPC | Level | Weight cognitive function | weight |
|--------------------|--------------------|------------|---------------|-----|-------|----------------------------|--------|
| Maintain | Execute | Action missed | 0.00 | 3 | Adequacy of MMI and operational support | inappropriate | 5.0 | 3.3170 |
| Available time | | | | | Adequate | 0.5 | 2.5687 |
| Availability of procedures/plans | | | | | inappropriate | 2.0 | 2.6106 |

The human failure probability is calculated using Eq. (6) and Eq. (7) in CREAM.

$$\omega = \prod_{i=1}^{m} \omega_{i} \cdot \prod_{i=1}^{n} \omega_{CPC}$$

(6)

$$CFP_{AD}^{i} = C_{FP_{bi}}^{i} \cdot \omega$$

(7)

In these equations, $\omega_{i}$ ($i = 1, 2, \cdots$) is the weight of the $i$th CPC level of the different cognitive functions, $\omega_{CPC}$ ($i = 1, 2, \cdots$) is the weight of the $i$th CPC itself, and $CFP_{AD}^{i}$ is the adjusted cognitive failure probability of the $i$th cognitive activity.

Then, $CFP_{AD}$ for safety inspector in this accident is acquired with Eq. (6) and Eq. (7):

$$CFP_{AD} = 0.003 \times (5.0 \times 0.5 \times 2.0 \times 3.3170 \times 2.5687 \times 2.6106) = 0.3336$$
Where $\text{CFP}_{\text{adj}}$ is the adjusted cognitive failure probability of the cognitive activity for “maintain” of safety inspector in coal mine.

In this accident, there is no correlation among activities for “maintain” is the sole activity. Therefore, HFP for safety inspector in this accident is 0.3336.

4.5. Analyze consequence

Table 8 shows the results of this paper and [26] acquired with modified extended method and traditional extended method in CREAM respectively. As listed in Table 8, the level of these CPCs upon safety inspector in this accident is consistent with the results presented by [26], which demonstrates that the proposed approach is valid. Besides, this accident report shows that the function item of safety inspector upon gas monitor performed by safety inspector was not well performed, which lead to the failure in the supervision and inspection. Distinctly, the results got with proposed quantitative model are very approach to the reality of situation, and can make the effect of HFP for safety inspector on accident more prominent.

| CPCs                              | $L_T$ | $L_P$ | $P_T$ | $P_P$ |
|-----------------------------------|-------|-------|-------|-------|
| Adequacy of MMI and operational support | inappropriate | inappropriate | 0.006 | 0.3336 |
| Available time                     | adequate | adequate |       |       |
| Availability of procedures/plans   | inappropriate | inappropriate |     |       |

Where $L_T$ and $P_T$ refer to the CPC level and HFP that acquired with traditional extended method in CREAM, while $L_P$ and $P_P$ refer to the CPC level and HFP that acquired with proposed methodology.

5. Conclusion

An effective and comprehensive methodology to quantify and predict safety inspector reliability during coal mine operation can be favor to operation of industry in safety environment. For reducing the occurrence of coal-mine accidents and enhancing safety in coal mine operation, this paper induces a novel methodology to conduct safety inspector reliability analysis in coal mine operation.

In the study, the factors affecting safety inspector is developed base on the factors affecting safety inspector perception, cognition and decision making that acquired with task decomposition and psychological expert experience. Thereafter, reliability assessment is conducted with a comprehensive methodology. The developed modified extended methodology not only makes actual contribution to the coal-mining industry, as well as theoretical literature. Accordingly, the spotlights with respect to the study are made as following:

A developed CPCs framework table for safety inspector to quantify scenario upon coal mine operation.

Systemic quantitative model to predict safety inspector reliability.

A crucial failure with respect to safety inspector to demonstrate the validation of proposed approach.

Improvement security of coal mine operation in coal-mining industry.

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