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A STUDY ON THE OSH PERFORMANCE MODEL IN COAL-FIRED THERMAL POWER PLANTS

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Abstract:
Coal-fired Thermal Power Plants (CTPP) consist of many sections that are risky in terms of occupational safety. CTPP are also important part of electrical Energy Logistics systems. Then it is of great importance to examine which parts of complex systems such as coal-fired thermal power plants are more important in terms of occupational health and safety. CTPP are divided into nine main sections as coal parking area, ash and slag disposal facility, boiler maintenance service, mechanical workshop, measurement and control service, turbine maintenance service, technical office, tea and rest room and use of company vehicles section. In this paper, a weighting and ranking study has been conducted in terms of risk analysis of nine departments in CTPP. For this purpose, accident statistics according to years were obtained from an actively working CTPP, and the results obtained with AHP and the risk significance weight values were compared with these results. Since CTPP are very complicated and complex structures, it is of great importance to determine the risk levels of the departments more significantly and objectively from the point of view of OHS. From this point of view, CTPP were analyzed for the first time within the scope of OHS with the Analytical Hierarchy Process (AHP), which is a multi-criteria decision-making (MCDM) method. According to the findings obtained in our study, coal parking area, ash slag disposal facility and boiler maintenance service were determined as the most risky sections in terms of OHS. With this study, a more effective assessment can be made in terms of OHS for CTPP, so that work accidents will be reduced, energy production will be carried out in a safer and more sustainable way.

Keywords:
AHP, coal-fired thermal power plants, occupational health and safety, MCDM, Energy Logistics

1. Introduction

The electrical energy produced in coal-fired thermal power plants is the most critical component of modern life. The largest part of the electrical energy used in the world is covered by fossil fuels.Coal-fired thermal power plants are planned according to the principle of continuous operation for electricity generation. Coal-fired thermal power plants have been commissioned to balance the change in different renewable energy sources both in the world and in developing countries such as Turkey since 2010 (Yılmazoğlu and Durmaz, 2013).

Compared to renewable energy plants, coal-fired thermal power plants are more complex systems and their operation and maintenance are more risky in terms of electricity generation. Coal-fired thermal power plants, in general, are not compatible with change within the enterprise. In addition, the values and operating criteria of many of the equipment in their structures should be closely monitored and emergency intervention should be required.

In coal-fired thermal power plants, the coal transported by belts to the coal parking area is dumped into different storage areas and kept for separation into special sizes.

Coal, which is converted into a homogeneous fuel to reduce the grain size is sent to the mills to be burned at the power plant with homogeneous mixing systems. Coal in suitable grain size milled in the mill generates heat energy by

burning in boilers, and the water heated in boiler serpentine pipes is converted into hot steam with the generated energy.In steam turbines, heat energy is converted into kinetic energy. With the kinetic energy in the turbine, electrical energy is generated in the generator connected to the turbine rotor. A coal-fired thermal power plant consists of departments with different functions and very different equipment in these departments. The main ones are; coal parking area, mills, boilers, turbines, mechanical workshop, electricity generators, cooling towers and auxiliary equipment (Başaran, 2017).

Coal-fired thermal power plants have complex equipment that converts heat energy into mechanical energy. The place where electricity is generated is a generator connected to a steam turbine. Coal-fired thermal power plants use energy obtained from steam. Since all thermal power plants have thermal efficiency limited by Carnot efficiency, they produce waste heat, and this waste heat must be disposed of to the environment by cooling towers and condensers (Yılmazoğlu and Durmaz, 2013).

There are many important dangers and risks that may cause occupational accidents and occupational diseases in the departments of coal-fired thermal power plants. As a result of this, occupational health and safety in thermal power plants should be given serious attention in the electricity generation process. Due to the fact that the risks in this energy sector are many and high, occupational health and safety should be given more importance in coal-fired thermal power plants and studies in this area should be increased (Ersoy vd., 2022).

The efficiency and safety of electricity production in coal-fired thermal power plants are very important. The number of occupational accidents in our country is still very high compared to developed countries, despite the improvements in Occupational Health and Safety. Occupational accidents in thermal power plants are an important and multidimensional problem. One of the important problems of working life in these places is work accidents that occur at work. A safe working environment is of importance from a human and social point of view.

The history of occupational accidents in our country shows that technological investments, legal regulations, academic and scientific institutions, the state, industrialists and employees have failed to fulfill their duties in the field of occupational health and safety during the process. The reason for most of these work accidents that occur is that lessons have not been learned from previous work accidents. Safe working environments can be created by analyzing accidents and taking preventive measures (Horozoğlu,2017).

The measures to be taken to minimize the losses caused by occupational accidents and to provide a safe working environment are called occupational safety. The purpose of occupational safety is to proactively protect employees, the workplace and production from all kinds of risks. There are many risk factors that threaten the health of employees in the workplace, which can cause occupational diseases and even deaths. Occupational health and safety studies have a serious role in preventing occupational accidents and occupational diseases, providing physical and psychological satisfaction to employees, as well as increasing workplace productivity by providing a safe working environment. The fact that they conduct risk analyses for these studies at workplaces depends on their awareness of the current state or development of OHS-related methods and activities.

In terms of determining the regions where coal-fired thermal power plants are the most risky from the point of view of OHS, CTPP are divided into 9 sections; then the sections where the most important and most accidents occur are statistically tabulated.it is shown by analyzing in 1. According to the values in this table, in the distribution of occupational accidents by units, it is observed that the most accidents occur at the coal parking lot, boiler maintenance service and ash slag disposal facility, respectively. The rankings of these departments in terms of the number of accidents vary by year. In order to eliminate the impact of this change and to be able to more objectively and scientifically sort the most risky sections in terms of OSH in coal-fired thermal power plants, a weighting and prioritization study was conducted using the AHP method in this study.

Coal transportation band and coal parking area, cables in all services of the power plant, coal transportation in coal storage and conveyors, transformers, mills and boilers have been found to be a priority in terms of occupational safety. Ersoy and his colleagues have seen in their studies that when the risks are prioritized, there are explosions, fires and electricity. They informed about the risks encountered in the energy sector and the measures to be taken. It has been emphasized that there are serious work accidents due to human errors during maintenance works at coal-fired thermal power plants. The leading causes of human error have been found to be carelessness, inexperience, shift work, lighting, ventilation, maintenance culture, time pressure. In the studies they examined, they emphasized the serious safety and health conditions of working at height, installation under pressure and during operation as important activities. They explained the continuous improvement of performance in thermal power plants and the

safety measures to be taken (Ersoy vd., 2022). CTPP are hierarchically divided into sections in terms of OSH risk factors and performance, and this analytical hierarchical structure model is illustrated in Figure 1.
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Table 1. Distribution of Occupational Accidents in 2018-2021 for one of the CTPPs

Units	2018		2019		2020		2021		2018-2021	
	Number of accidents	Annual accident rates %	Number of accidents	Annual accident rates %	Number of accidents	Annual accident rates %	Number of accidents	Annual accident rates %	Avarage Number of accidents	Average annual accident rates %
Coal parking area	14	35%	11	42%	7	37%	9	36%	10	35%
Ash slag disposal facility	8	20%	5	19%	3	16%	4	16%	5	17%
Boiler maintenance service	12	30%	9	35%	8	42%	10	40%	10	35%
Mechanical workshop	4	10%	1	4%	0	0%	1	4%	2	7%
Measurement control	0	0%	0	0%	0	0%	0	0%	0	0%
Turbine maintenance service	1	2.5%	0	0%	1	5%	0	0%	1	3%
Technical office	0	0%	0	0%	0	0%	0	0%	0	0%
Tea and rest room	1	2.5%	0	0%	0	0%	1	4%	1	3%
Use of company vehicles	0	0%	0	0%	0	0%	0	0%	0	0%

Total	40	100%	26	100%	19	100%	25	100%	29	100%

It has been emphasized that there are serious work accidents due to human errors during maintenance works at coal-fired thermal power plants. The leading causes of human error have been found to be carelessness, inexperience, shift work, lighting, ventilation, maintenance culture, time pressure. In the studies they examined, they emphasized the serious safety and health conditions of working at height, installation under pressure and during operation as important activities. They explained the continuous improvement of performance in thermal power plants and the safety measures to be taken (Ersoy vd., 2022). CTPP are hierarchically divided into sections in terms of OSH risk factors and performance, and this analytical hierarchical structure model is shown in Fig.it is shown in 1.

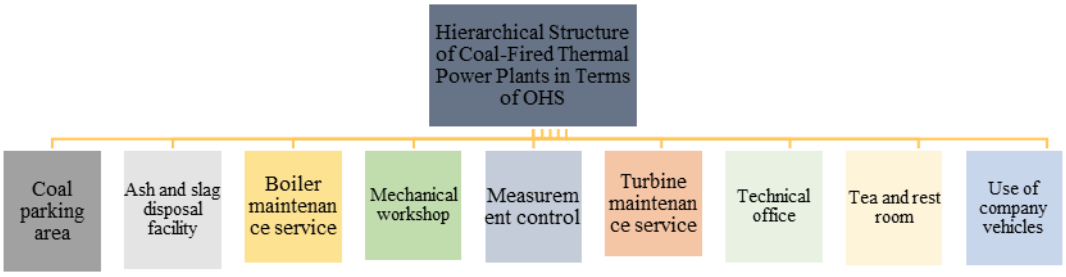

Figure 1. Hierarchical Structure of Coal-Fired Thermal Power Plants in terms of OHS

Measuring the impact of technical and legal regulations on the OHS performance of coal-fired thermal power plants is an important problem. It is necessary to observe whether the changes made regarding OHS are taking coal-fired thermal power plants to a better place or a worse place. Coal-fired thermal power plants are in the position of continuing their improvement studies with current situation analyses in order to maintain their assets effectively and efficiently. In the literature, when coal-fired thermal power plants want to measure the change in OHS performance from year to year, they usually look at a limited number of reactive indicators, such as the number of occupational accidents that occurred in previous years. Sometimes the OHS performance of a thermal power plant is evaluated by an observation made at the power plant by an expert within a limited period of time. The current status information obtained by using a limited number of indicators for coal-fired thermal power plants does not indicate the actual performance of the power plant. There is no objective and sector-specific OHS performance measurement system that is accepted as a partner and can be used in a simple way.
At this stage, the three most risky parts of coal-fired power plants in terms of OHS performance were determined by weighting with the AHP method. Accordingly, it has been determined which sections should be given importance in terms of OHS in coal-fired power plants. Thus, the basis for the development of an objective and practical OHS performance model proposal for coal-fired power plants has been introduced.

2. Evaluation of the Importance of the Departments in the CTPP from the Point of view of OHS

2.1. Analytic Hierarchy Process(AHP)

AHP is a multi-criteria decision-making technique that ensures that subjective and objective factors are considered in the decision-making process. AHP allows decision makers to participate actively in the decision phase and provides managers with a rational basis for their decision making. (Dey,2010).
Solving problems related to AHP decision making is the most widely used method. Same criteria used in decision making problems. Importance scale and decision alternatives among decision makers evaluations may differ. This in solving decision problems involving diversity AHP can provide effective decision making. AHP is a common criterion of homogeneous elements or dominates pairwise comparisons by attribute is a measurement theory about the derivation of priorities (Saaty,1990).

The AHP was first introduced by Myers and Alpert in 1968 (Myers and Mark,1968). The AHP method was developed as a model by Professor Thomas Lorie Saaty in 1977 to solve decision making problems. The AHP method helps decision makers by showing the correlation between objectives, criteria, sub-criteria and alternatives to model the most complex problems in a multi-level hierarchical structure. AHP represents a problem as a hierarchical structure with the goal at the top. The next levels contain the criteria and sub-criteria, while the alternatives are at the bottom of the hierarchy. (Srdjevic and Srdjevic,2013).

After the hierarchy is established, the criteria calculation of importance levels against each other makes. Bilateral between criteria and alternatives in AHP Thomas L. for the creation of comparisons. 1-9 scale reference created by Saaty taken.

The implementation steps of this method are as follows:

1.The problem is defined, and target is determined.

2. Criteria and sub-criteria are determined.

3. Alternatives (options) are determined.

4. Based on the objectives, the main criteria and the lowest-level alternatives are created in a hierarchical structure.

5. In order to determine which of the alternatives and criteria has priority, a pairwise comparison between the alternatives and the criteria is made using the scale stated in Table 2. Comparison matrices (nxn) are of square matrix dimensions. The pairwise comparison scale in Table 2 is used when constructing comparisons and matrices. (Saaty,1986).

6. for each column in the pairwise comparison matrix, column totals are taken. The normalized matrix is formed by dividing the elements of the matrix by the corresponding column sum.

7. In the normalized matrix, each line created for alternative, or criteria totals are taken. The priority vector matrix is obtained by dividing by the number of criteria.

8. In the weight matrix obtained with the weight vector, the weight values of each criterion or alternative are multiplied by the column elements of the pairwise comparison matrix of that criterion or alternative to obtain the total weighted matrix.

9. When calculating the consistency ratio, the CI value is found first:

$CI=(\lambda max-n/(n-1)$ (1)

where CI = Consistency Index(Saaty,1990).

10. In the last step, the consistency ratio can be calculated by the combination of the values of the randomness scores and the combination of CI, where CR = Consistency Ratio and RI = Randomness Indicator. The consistency ratio in the AHP method should be less than 0.10. If the calculated value is greater than 0.10, the pairwise comparison matrix should be checked again, and the steps are repeated after the corrections to be made.

11. The highest value from the calculated values alternative suitable to us that can be chosen as a result shows the alternative.

Table 2. Pairwise Scaling Coefficients for AHP

Numerical Value	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Low importance of one over another	Experience and judgement slightly to moderately favor one activity over another
5	Essential or high Importance	Experience and judgment highly favor or take precedence over one activity.
7	the importance shown	One activity is significantly favored over another, and its priority is shown in practice.
9	Absolute importance	Evidence of preferring one activity over another is to the greatest possible degree.
2, 4, 6, 8	judgement value between two intermediate values	They are preferences between 1, 3, 5, 7 and 9 weights.

The most important step for reliable and accurate evaluation of OHS performance in coal-fired thermal power plants is expert it is the correct determination of the degrees of importance of the 9 sections in the CTPP relative to each other with the dual comparison matrix with their opinions. For this purpose, 12 experts who worked as OHS specialists in CTPP in different regions were asked to fill out a binary comparison matrix in the size of 9x9; the geometric averages of these obtained values were taken, and the importance weights of the sections were obtained using the Super decision program.

2.2. Methodology

The process of determining the importance and weight levels of the departments in the CTPP from the point of view of OHS was carried out as follows:

- Firstly, the literature review was conducted and the occupational accidents in CTPP were examined in detail.
- The risk factors that emerged from this literature review study were evaluated by face-to-face interviews with 9 OHS specialists who worked in CTPP.
- In this part, which is the basis of our study, the analytical hierarchy process (AHP) method was applied to determine the priority weights of the departments in the CTPP in terms of OSH and risk factors.
- For this purpose, experienced OHS experts working in CTPP were interviewed and asked to evaluate the bilateral comparison surveys, which are a realistic and objective technique, according to the 1-9 scale of Saaty.
- After the geometric averages of the scores obtained from the experts were taken, the values were entered into the Super Decision program and evaluated in order to apply the AHP method to the results in the binary comparison matrix. Thus, with the AHP method, it is aimed to evaluate the order of importance of coal-fired thermal power plants in terms of OHS by comparing each risk factor individually with the others by occupational safety experts and to determine the importance weights and solve the importance weights.
- The important weight values of CTPP have been obtained from the point of view of OHS.
- According to the results, the sections of the CTPP were sorted in terms of OHS; the results were compared with the accident statistical values and the values in the literature.
- The final ranking results obtained have been discussed with experts and their suitability has been evaluated.

According to the opinions received from experts, an analytical hierarchical structure has been established in terms of risk analysis for the 9 main departments in CTPP. According to this analytical hierarchical structure, 71 risk factors were determined at the Coal park site, 47 risk factors at the ash and slag disposal facility, 68 risk factors at the boiler maintenance service, 79 risk factors at the mechanical workshop, 42 risk factors at the measurement control service, 84 risk factors at the turbine maintenance service, 54 risk factors at the technical office, 47 risk tea and rest room, 45 risk factors at the use of company vehicles, and as a result, a total of 546 risk factors were determined for CTPP . In this study, the weighting results of only 9 main sections for CTPP in terms of OHS have been given.

In order to determine which of the 9 main sections is more important in terms of OHS in coal-fired power plants, the Super Decision program was used. The values and screenshot obtained from this program are shown in Fig.3; comparative results are given in Fig.4 and Table.4.

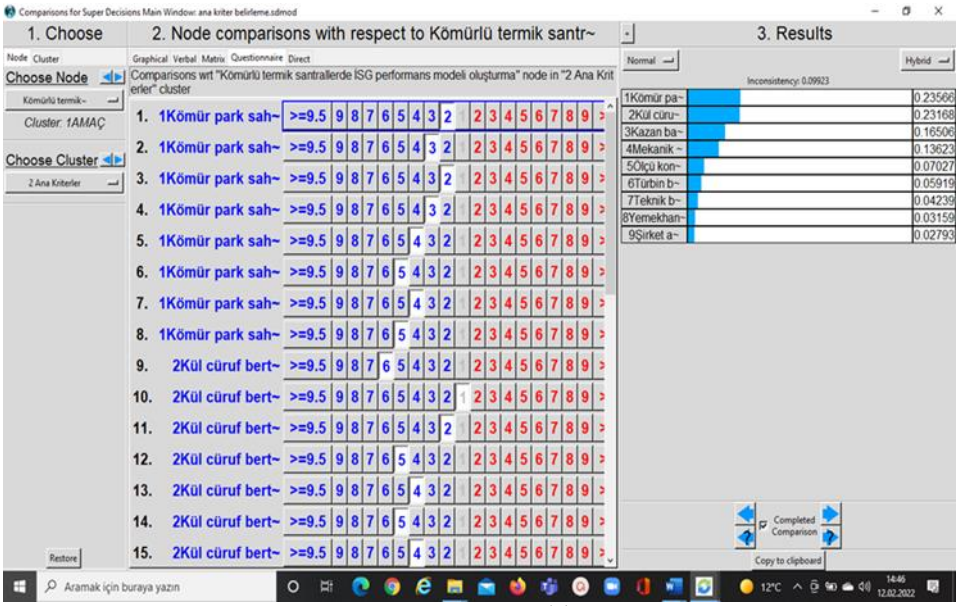

Fig.3 : Screenshot of SuperDecision Results about CTPP analysis according to OHS subject

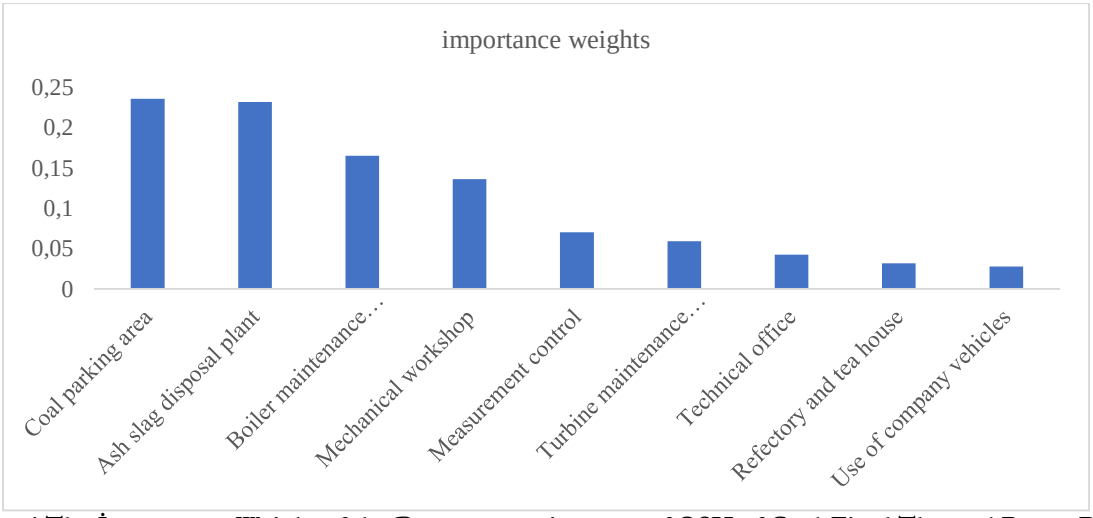

Figure 4 The İmportance Weight of the Departments in terms of OSH of Coal-Fired Thermal Power Plants

Sections of Coal-Fired Thermal Power Plants have been analyzed within the scope of OHS with the Analytical Hierarchy Process (AHP). It is consistent because the consistency ratio is 0.09923 <0.1. When the sections of coal-fired thermal power plants were examined in Table 4 in terms of OSH risk factors, it was revealed that the section with the highest weight was the coal parking area (0.23566). After that, it was found that the most important departments of CTPP in terms of OSH with ash slag disposal facility (0.23168), boiler maintenance service (0.16506), mechanical workshop (0.13623), measurement control (0.07027), turbine maintenance service (0.05919), technical office (0.04239), tea and rest room (0.03159), use of company vehicles (0.02793) are we can specify. Table with the results obtained with AHP. It has been found that it is also compatible with the average values of 4-year accident statistics for a CTPP in 1. Accident statistics show changes according to years; it is seen that the results obtained with AHP are more reliable in terms of risk weighting.

According to the results we obtained in our study, it was found that the most risky section in terms of OHS in CTPP is the coal parking area, and the least risky section is the use of company vehicles (Table 4).

Table 4. The Main Sections of Coal-Fired Thermal Power Plants in terms of OHS

Main sections	Criterion importance weights	Consistency ratio (CR)	Total accident rates %
Coal parking area	0.23566	0.07038	37
Ash slag disposal facility	0.23168	0.04134	17
Boiler maintenance service	0.16506	0.09591	35
Mechanical workshop	0.13623	0.09645	7
Measurement control	0.07027	0.09454	0
Turbine maintenance service	0.05919	0.08982	3
Technical office	0.04239	0.08092	0
Tea and rest room	0.03159	0.09531	3
Use of company vehicles	0.02793	0.09655	0

3. Conclusion and Discussion

Coal-fired thermal power plants in Turkey are old and contain many risk factors and are seriously important in terms of occupational accidents. We have prioritized 546 risk factors that we have determined by conducting a comprehensive risk analysis in all departments of coal-fired thermal power plants on a departmental basis using the AHP method. One of the multi-criteria decision-making methods in coal-fired thermal power plants, AHP comprehensively 9 sections were analyzed and evaluated. Thus, the 3 most important sections in terms of OHS (coal parking area, ash slag disposal facility, boiler maintenance service) have been identified. The accidents that occurred between 2018-2021 at coal-fired thermal power plants were examined and according to the study, it was found that the accidents were mostly in the age group of employees aged 41 and older, and in the early years of primary school Decedent employees, although in recent years, it was concluded that high school graduates had more accidents when the enterprise took care to employ qualified personnel. When we look at the days when accidents occur, it is noteworthy that there is a higher percentage of accidents on Fridays. Looking at the accident hours; it was observed that the number of accidents was higher during the night shift in the study. The study covers all units of coal-fired thermal power plants, and in the distribution of occupational accidents by units, it is observed that the accidents occurred first at the coal parking area 37.2%, boiler maintenance service 35.5% and ash slag disposal facility18.2%. It is seen that the distribution of occupational accidents by units we examined between 2018-2021 confirm each other with the order of importance we found the sections of coal-fired thermal power plants with AHP. According to the results obtained in our study, based on these three risky sections for coal-fired thermal power plants, the foundation of the work to create an OHS performance model to prevent work accidents has been laid.

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