

# **Application of Factor Analysis to Determine the Parameters of Planning Work-Zone in the Road Repair and Maintenance**

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## **Abstract**

Building and maintaining transport infrastructure is essential for economic and social development of each country. The high costs of repair and maintenance of the existing road networks required to manage the road repair and maintenance and systematic planning for this process. The scope of where the operational performance of road repair and maintenance are carried is called work zone. The measures are carried in the work zone caused traffic and increased the likelihood of traffic accidents. For this reason, in addition to repair and management operations, the traffic guidance and control with the aim of accelerating projects implementation, safety of personnel as well as users is important. In this regard, a number of related staff were selected by the simple random sampling method and Kukran formula and were asked them to respond to a questionnaire with approved reliability and validity. The results of questionnaires were used in factor analysis method in three dimensions form include personal safety, environmental protection and cost reduction as the main factors. In this study, in the first step by a questionnaire tried to identify and summarize the key factors among the effective factors on the successfulness of pavement maintenance and road infrastructure projects and then in the second step, by factor analysis tried to form a matrix to evaluate these factors. According to standard of factor analysis method the factor 1 to factor 3 with 85% had the greatest impact on the performance of pavement maintenance and repair activities. These factors can be summarized in a set of measures such as restrictions on the movement of heavy vehicles in the scope of work zone, work in an appropriate hour and dividing the high tasks into smaller tasks.

***Keywords:** Maintenance, Construction, Environment protection, Factor Analysis, pavement Construction,*

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## **1.0 Introduction**

Maintenance of roads is one of the responsibilities of engineers of the civil administrative jobs. In recent years the need for repairs and maintenance of buildings and road pavement has increased and significant efforts are currently being performed to optimize parameters such as cost, safety and to decrease environmental issues. The annual cost of road repair and maintenance are billions of dollars in the world and also in Iran, although, the majority of planning decisions are based on the experience and personal judgment, which isn't always the optimal choice. For reducing the operating costs and the environmental issues at work zones the indicators such as dimensions (length and width) of work zone, the stopped-time delay and used equipment are efficient. In this study, to improve these indicators a survey is gathered from the users, managers and experts associated with this operational performance to determine the effects of each factor and use them for building a new work zone. One of the advantages of this methodology is using the actual work zone and feeling of personnel in the actual work zone. The feeling of personnel of the condition and place of operations has a great impact on the rate of efficiency and cost reduction and could display the results more realistic. So far, there is no research on the effective factors on designing work zone. Reducing the cost and time delay of travelers was the focus issues of other researches. In this study, using factor analyses, the various properties of geometric and environmental pavement repair and maintenance work zones are selected and by the design of the questionnaire, the most influential factors on reducing environmental issues, costs and increasing safety is determined.

## 2.0 Literature Review

The road maintenance is associated with increasing traffic safety and environmental protection. ZHU et al. 2013 have been proposed Index System for High Way Maintenance Management which take ideas from Shenzhen City construction Project [1].

This System index includes five aspects: environment protection, cost, progress, quality, Safety, Sub-goals is determined in this method and new index is defined for each one. For example, the assessment of environmental protection index of maintenance is done by the table (1).

**Table 1:** Environmental protection index of maintenance[1]

<b>Evaluation</b>	<b>Evaluation content</b>	<b>Considered aspects</b>
<b>Operation Pollution</b>	<b>Sound</b> <b>Air</b> <b>Water</b>	<b>Noise</b> <b>Waste gas</b> <b>Surface runoff</b>
<b>Green maintenance</b>		<b>Maintenance energy saving</b> <b>Waste disposal</b> <b>Waste cycle using</b>

Research Zhou et al., shows, economic- benefit index is usable for using in Asphalt pavement Maintenance technologies Evaluation Model. They provide a new model for economic evaluation of maintenance techniques by the help of statistic theory. They compare three methods such as milling thermal shop, micro-Surfacing, Hot asphalt overlay and concluded Micro-Surfacing is better economically with the conditions of their country. [2]

Kehagia and Mouratidis in 2012 in the investigation, the status of two-lane roads in Greece country and the effect of maintenance of road on traffic safety and investigating the reduction of environmental problems. About the proper planning (well planned schedule) performance in maintenance, was concluded, cause to infrastructure protection (Infrastructures) and prolongs the life of the pavement, shoulder and other road facilities and Road safety periodic inspection and frequent inspections road, pavement and infrastructure by trained experts cause to increase cost-effective and goals Safety, environmental and economic benefits can be achieved [3].

Enshassi R et al. research, in 2014, is about the Factors affecting safety performance in repair and maintenance project, lack of training and certification of competence, is the main reason in injuries and accidents. The results also showed that the increase in cost and imposing psychological burden on workers is the most common effects of events in repairing and maintenance projects. They used method in the study, a questionnaire was designed and it was based on previous studies. [4]

Christopher and colleagues' studies reported in 2015, which focused on the raised gases from facilities construction workshop, it became clear, the most pollution from traffic waiting vehicles. The other source of pollution related to the material which amount is very low, they also have pointed out to the results of studies to the methods of reducing raised gases [5].

In a study by Denisow and colleagues in 2013, to use ontologies and multi-agent systems involved in the planning and the maintenance of road intersections. In their results of research point to the design of intelligent software mentioned in this planning, it is also stated that the successful programs, is necessary to update the input data of system and dynamically changeable [6]. In Morgado and Neves' research results in 2013, pointed out that the most important factors are important in planning and decision-making in work shop environments in pavement maintenance, working hours nocturnally or work at the end of the week and reduction of travel latency time, increase safety and the protection of the environment (especially noise) [7]. As it was observed in previous studies, the factors such as the environment, economy, safety and other

factors have been studied, but most notably are not determined in the designing construction workshop and maintenance and repair of pavement. In this paper, according to these variables and factors, the preliminary questionnaire is designed and primary factors were selected then these factors were prioritized by factor analysis.

### **3.0 Research Methodology**

Factors Analysis is a statistical method used in the process of validating modern tests of intelligence that traces its roots to the work of the eminent statistician Karl Pearson (1901). When the number of variables is large and the relationships between them are unknown, factor analysis used to determine the most effective factor. In this method, the variables are putted in the factors so that from the first factor to the following factors the variables are reduced. Therefore, the most effective factors of the variables are the initial factors [8, 9].

Dimensions and conditions of work zone maintenance are defined in different countries guidelines and regulations. Road safety regulations in chapter 7, is provided how to establish safety signs of work zone for the repair and construction of the pavement [10]. Recent research findings showed that most of them have tried to explain the travel time delays by the geometric conditions and traffic and the safety effective parameters by relationships among transport knowledge, Although, there has been paid less attention to human aspect and their views and perceptions on the safety and environmental protection[11]. In this study, the human different aspect and maintenance and construction technology for the protection of the environment and safety has been discussed. For this purpose the descriptive statistics and factor analysis are used to determine the main problems.

#### **3.1 Data classification using factor analysis method**

The initial factors in maintenance and repair work zones are the length and width of roads, the type of equipment used in operations, the number of heavy vehicles and trucks, traffic volume and environmental conditions. Considering the fact that the quality of the operational performance is a quality parameter (not a quantitative) and evaluate it with quantitative approaches is very difficult. A field survey have carried out in the road repair work zone showed that the quality of the operational performance is dependent on the conditions of the workers and how much attention paid to their comments. So twenty-five factors were selected and in the questionnaire form was asked.

#### **3.2 Data classification using factor analysis method**

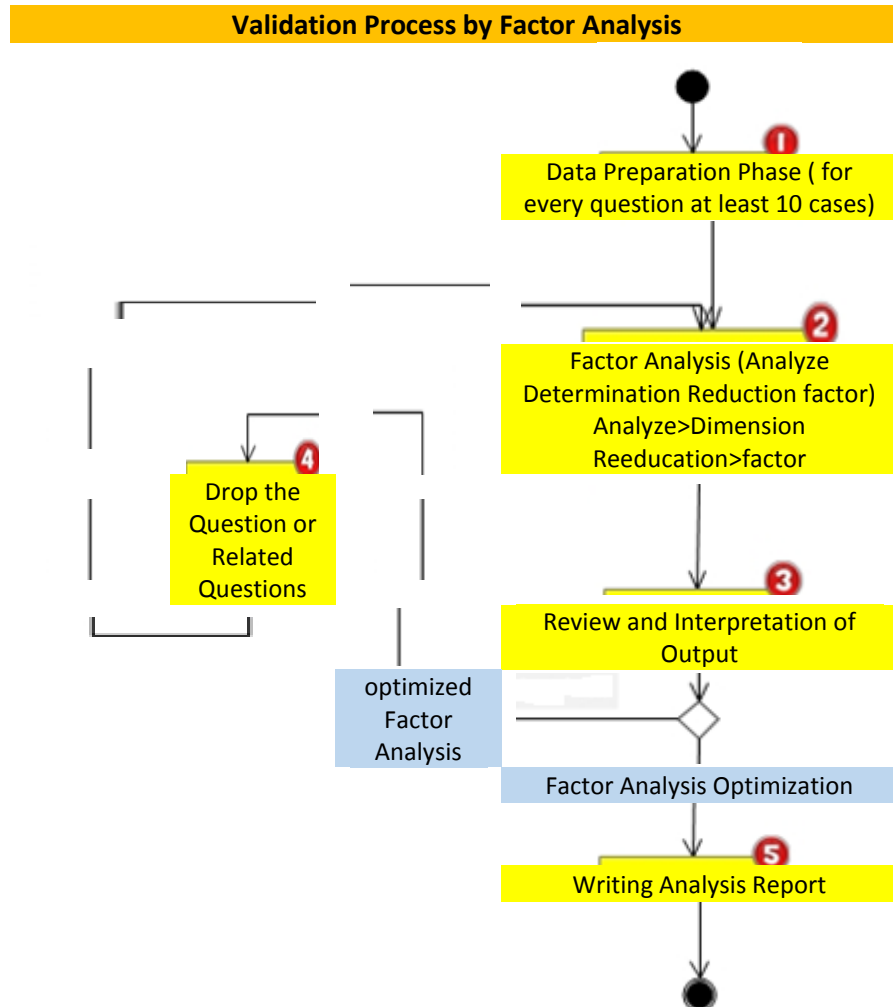
A factor analysis technique used for summarizing the high data and components, while, the data summarizing is done in the ways that are meaningful. In this study, the data matrix is a matrix with a column of 25 questions (index) and a row of 35 questions that were described by descriptive statistics (Apendixe.1).

The correlation matrix is used for the later calculation and interrelationships between indicators (and comments). By using the matrix factor, the common factors and the relative importance of each indicator is measured. In this study, factor rotations were used to simplify the structure of the matrix.

Factor analysis is a statistical method used to reduce the number of variables. The basic model can be expressed as the score of factor  $i$  to variable  $j$  and the sum of the coefficients of the scores in the smaller number of variables which called factors. The model is a linear model that can be wrote as an equation[12]:

$$Z_j = a_{j1} \cdot F_1 + a_{j2} \cdot F_2 + \dots + a_{jp} \cdot F_p \quad (1)$$

If KMO (Kaiser-Meyer-Olkin) related to this method is less than 0.5, the data for analysis of the main factors is not suitable and if the value is between 0.5 and 0.69 to analysis with more caution, if the value is greater than 0.7, correlations between data for analysis would be appropriate [13].



**Figure 1:** Simplified research model layout [14]

### 3.3 Key variables and the questionnaire items

Research items include the following elements: employment history, education level and job category which the respondent is asked to tick the appropriate box. Likert scale of 1 to 6 (strongly agree - agree – somewhat agree- disagree - strongly disagree – no comment) was selected (sample questionnaire is provided in the following text.). Items of this questionnaire were examined the following factors, in any case, between 2 to 7 questions were asked.

1. Is the scope of work zones for the pavement repair has efficient on the safety, increasing environmental pollutions and reducing the efficiency of operations?
2. Does the implementation of operational performances at special time of the day (daytime versus nighttime) has efficient on increasing the number of accidents and the efficiency of operations?
3. Does dividing the scope of the workplaces into the smaller areas is appropriate?

4. What are the most damaging environmental factors to the workers (air pollution, noise or dust)?

5. Is the use of technology and new materials is effective on reducing the environmental pollutions and injuries?



**Figure 2:** A) Part of the main routes in the study area, B) simultaneity of operational performance for opening the routes and utilization of the rout in the area of the study[15]

## 4.0 Results and Discussions

To review comments related to the maintenance of road pavement and determine important parameters, the construction projects were obtained from the Department of Roads and Urban Development in the south of Kerman, Iran. The accidents statistics about 126 was reported in 2015. The length of the study area was 1262 kilometers, of which 35 construction and maintenance operations are running. 185 km asphalt overlay, 37 km widening and improving routes and 9 cases removing black spots was completed. To collect information, a questionnaire was distributed among three categories of people.

1. The directors and staff of the Department of Road Maintenance.
2. The professionals and contractors of road construction and maintenance.
3. The Staff of road construction and maintenance at work zones.

40 questionnaires were distributed and 35 of them were returned and the data analyzed by spss21 statistical software [12].

### 4.1 descriptive analysis

The first step in any statistical analysis is descriptive analysis to help the researcher identify the population studied. The greatest number of respondents had work experience between 27 and 57 years (25%) and at least between 21 to 27 years (10%). The most respondents (28 percent) had an associate degree, 25 percent had a bachelor's degree and 3 percent had above a bachelor's degree. Figure (2) shows the descriptive analysis of the work experience and education level participant in the study.

### 4.2 Factor analysis of questionnaire

In the factor analysis model to identify principle components of the scope of pavements repair and maintenance work zone, the Scree plot shows the specific value for each extracted component, as starts with the greatest amount, the plot is always descending. The special value with further extracted factors slows down rapidly. The specific value of the eleventh factor is less

than one, so in the rotated component matrix until the tenth factor is calculated. Figure (3) shows the scree plot of the principal component analysis. According to the figure can be seen the first four components, shows more than 85% of the variance of data.

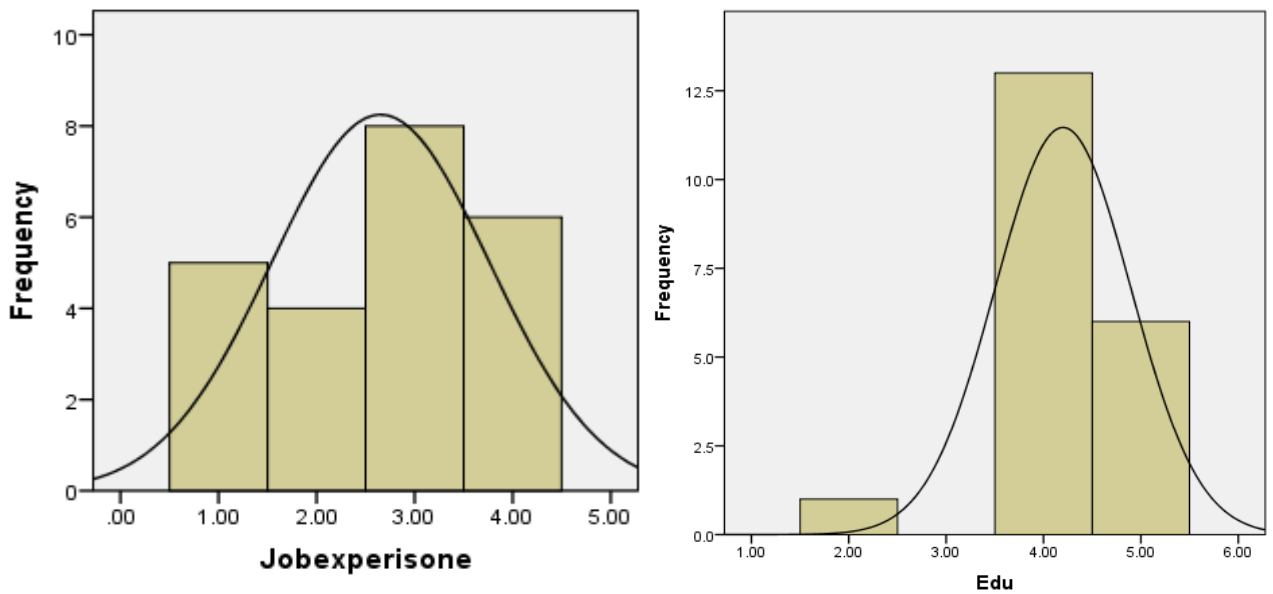
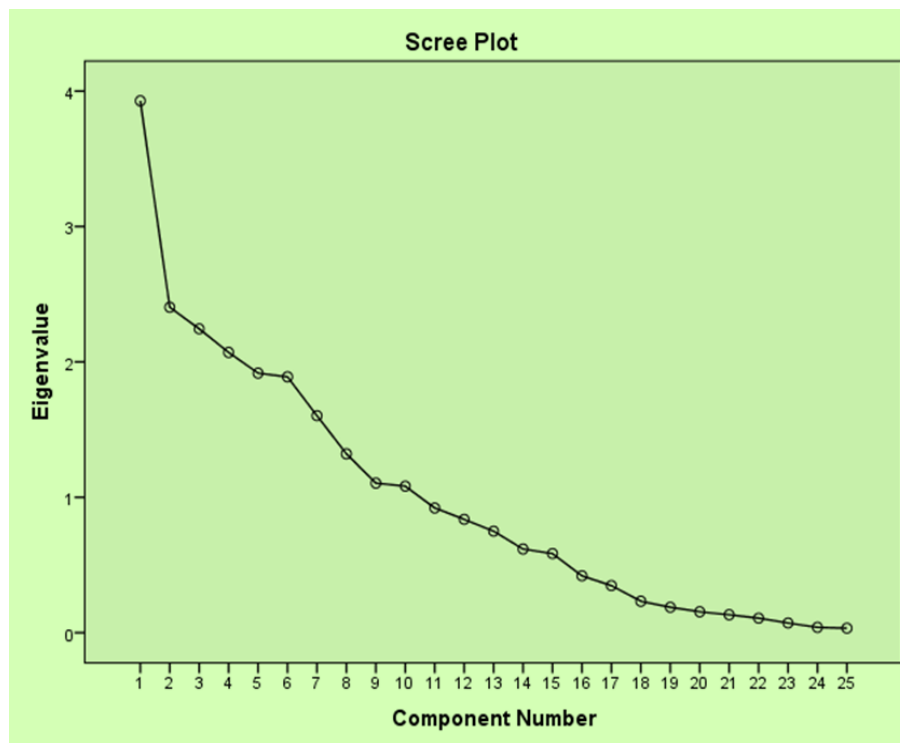


Table (2) shows the rotated component matrix. The aim of this matrix is to achieve a new status for factors to change them better. As can be seen variables of  $q_{15}$ ,  $q_{13}$  and  $q_7$  can be considered as a common factor, because their values in this column are more than 0.55 and has smaller amounts for other columns. These variables emphasize the effects of the type and volume of vehicles moving during construction and repair operations.



**Figure 3:** Factor Scree Plot in the principal component analysis method

**Table2:** Rotated Component Matrix.



Component Matrix <sup>a</sup>

	Component									
	1	2	3	4	5	6	7	8	9	10
q1	.087	-.493	.402	.378	.100	.037	.241	-.032	.153	-.131
q2	-.033	.011	.563	.063	.352	.004	.155	-.309	.334	-.059
q3	.529	.217	.022	.048	-.117	-.060	.575	-.094	-.024	-.167
q4	.156	-.517	.157	.209	-.483	-.321	.181	.092	-.097	-.158
q5	.174	-.065	.396	-.130	-.533	.320	.186	-.131	.105	.001
q6	.447	-.580	.077	.118	.293	-.062	-.110	.082	.208	-.155
q7	.298	-.047	.164	.129	-.157	.442	-.208	-.393	-.030	.586
q8	.565	-.316	.068	.365	.278	-.135	.101	-.082	-.233	.285
q9	.496	.454	.037	.231	.074	.375	-.015	.213	-.222	-.155
q10	.514	-.108	.089	.015	-.222	.223	-.108	.559	.139	.274
q11	.028	.161	.120	.489	.367	.573	-.113	.088	-.016	-.097
q12	.051	.231	.597	-.123	.406	-.430	-.286	.067	-.157	.002
q13	.643	-.288	-.169	-.116	.049	-.081	-.439	-.223	-.152	.024
q14	.546	-.437	.015	-.314	-.004	-.072	-.097	.520	.058	.019
q15	-.139	.313	.456	.375	.175	-.185	.031	.259	.191	.304
q16	.509	-.010	-.371	.149	.414	.053	-.181	-.193	.065	-.269
q17	.078	.282	-.419	-.164	.059	-.145	-.162	.076	.635	.114
q18	-.122	-.131	-.269	.038	.064	.637	.341	.154	.069	-.037
q19	-.066	.116	.609	-.406	-.198	.196	-.292	.034	.141	-.083
q20	.509	.130	.106	-.616	.097	.214	-.023	-.110	-.276	.010
q21	.498	-.088	.108	-.537	.229	.127	.292	-.224	.306	-.069
q22	.443	.522	.114	-.197	.188	-.212	.464	.227	-.179	.052
q23	.568	.340	-.325	.223	-.085	-.201	.086	-.023	.215	.185
q24	.360	.370	.176	.273	-.342	.100	-.422	.054	.084	-.472
q25	.540	.272	.028	.300	-.487	-.294	-.028	-.282	.082	.001

Extraction Method: Principal Component Analysis.

a. 10 components extracted.

25 questions in ten factors were extracted in the component score (factor) coefficient matrix. Whatever the value of these coefficients is closer to one, the factor has a more important role in the variance of the involved numbers, in these field coefficients greater than 0.5 are considered. Table (2) shows the rotated component matrix, in the first column items or questions (q<sub>3</sub>-q<sub>8</sub>-q<sub>10</sub>-q<sub>13</sub>-q<sub>14</sub>-q<sub>16</sub>-q<sub>20</sub>-q<sub>23</sub>-q<sub>25</sub>) can be considered as the first factor. Also in the second column q<sub>22</sub>, in the third column q<sub>2</sub>-q<sub>12</sub>, in the sixth column q<sub>11</sub>, in the ninth columns q<sub>17</sub> and in tenth column q<sub>7</sub> can be considered as another 5 important factors. According to the questionnaire, the important factors which were extracted from the written points, four factors can summarize to common factors as including:

- 1- Proper planning before the start of the work zone operations (increasing productivity)
- 2- On- time repair and service of construction machines (increasing productivity)
- 3- Strictly Implementation of the safety guidelines and regulations (increasing safety).
- 4- Using construction equipment such as filters to reduce the smoke and dust in the scope of the work zone (improving environmental conditions)

#### 4.2.1 Interpretation of safety at work zones

Important factors extracted from the questionnaires by factor analysis shows, environmental and weather conditions can affect safety, in hot weather increases the number of incidents, the results of the investigation correspond to Foster research in 2014 [16]. The most risk at work zones is for the workers who facing with the passage of heavy vehicles (usually flagmen). The best way for reducing accidents is the presence of traffic police.

#### **4.2.2 Interpretation of environmental conditions at work zones**

Factor analysis of the questionnaires shows, noise pollution reduction is the most environmental pollution factor caused by the use of modern equipment and technology. This result is consistent with results reported in 2014 by Olwin [17]. Also with strong controls can be reduced environmental pollution in operations. The most important air pollution caused by work zones and could damage to workers is smoke from passing vehicles and then dust and suspended particles in the air.

#### **4.2.3 Interpretation of productivity at work zones**

The analysis shows that the best time to increase productivity and efficiency is the daytime. The use of new technology and machinery is caused increasing the efficiency and volume of operational performance.

### **5.0 Conclusions**

The purposed factor analysis is used to determine the effective factors related to optimizing conditions of work zones for repair and maintenance of road pavement. In this study, at first according to previous studies the effective and important factors at work zones were identified, such as safety, the geometric dimensions of work zone, environmental conditions, the work hours related to light conditions. Then, with the help of statistical software and factor analysis the most important factors in optimizing the conditions of work zone were identified. From a total of twenty-five items, six important factors that had a greater impact on the improvement and repair construction were selected.

The results showed that factors in improving operating conditions are as follows:

- 1- To Increase work zones safety, the environmental conditions and the time are important factors.
2. To reduce the risk of the construction and repair pavement operations, preventing and limiting the movement of heavy vehicles, such as the route deviation are effective.
3. To reduce environmental pollution could be used the new materials and construction equipment.
- 4- noise pollution (due to the movement of cars and the machines of operational performances) is the most important pollutant factor in the scope of work zone which is harmful for the workers in the area.
5. The efficiency of operations could increase with good light hours (daytime).
6. Improve the condition of the construction machines, such as the use of modern equipment and on-time services could increase the efficiency of operations.

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## References

- [1] Zhu,J.chen,z. and sun , L. ,A method of constructor of index system for highway maintenance management , procedia-social and behavioral sciences 96 (2013) 1593-1602 Doi; 10.1016/j.sbspro.2013.08.181
- [2] Zhou,B. ,Zhang,C. ,Tsai,J. ,Guo,X. and Zhou,X. ,Asphalt Pavement Maintenance technologies Evaluation model, procedia-Social and Behavioral Sciences 96[208] 2115-2122, doI;10 . 1016/j.sbspro. 20B. 08 . 238.
- [3] kehagia,F.,Mouratidis, A. Living in the shadow of motorway; safety and maintenance on the old national road network, Procedia - Social and Behavioral Sciences 48 ( 2012 ) 2179 – 2189. Doi: 10.1016/j.sbspro.2012.06.1191.
- [4] Enshassi , A. , Risqa , E.and Arain , F Factors affecting safety performance in repair, maintenance .A lecration and addition (RMAA) projects, International Journal of sustainable construction Engineering & Technology , vol 5 , Issue 2, 2014 , pp25-38.
- [5] Denisav,M.V. , Kamaev,V.A. ,and Kizimi,A.V. , (2013),Organization of the repair and maintenance in road sector with ontologies and multi-agent system , procedia technology , (2013),819-825. doi : 10.1016/j. protcy.2013.12.091.
- [6] Christopher S. Hanson, Robert B. Noland, Greenhouse gas emissions from road construction: An assessment of alternative staging approaches, Transportation Research Part D: Transport and Environment, Volume 40, October 2015, Pages 97-103, ISSN 1361-9209.
- [7] <http://dx.doi.org/10.1016/j.trd.2015.08.002>.
- [8] Morgado,J. and Nevas,J. , (2013), An integrated Methodology for planning road pavement maintenance and rehabilitation interventions within High-Traffic contex, 13th WCTR, July 15-18 , 2013 Rio de Janeiro, Brazil , PP 1-20.
- [9] Sheykh al-Islam, Abdul Reza, Bagheri Khalili Fatemeh, Mahmudabadi Abbas, reduction of the inputs variables in the process of freeways traffic accidents modeling by using principal component analysis, Journal of Transportation Engineering, Vol 3, Issue 4, summer , PP 325-338,2011.
- [10] Chahouki Zare, M., Multivariable analysis method in SPSS software, Publications Faculty of Natural Resources, Tehran University, autumn, 2010.
- [11] Moghadas Nejad, F, Kheir Khah, M., (2015), the development of optimized geometry model to the workshop area, to reduction of the impact of on latency network transport operations, Transportation Journal, Vol. 11, issue No. 4, pp 355-377 .
- [12] Bayazidi, A, Oladi, B, Abbasi, N (2012) Analysis of the questionnaire data with the help of software SPSS, publisher Abed, page 306.
- [13] Planning & Management Organization, Ministry of road & Urban development, (2011), the basic principles of safety in road construction operations, Section 7, Publication 267, Tehran, page 106.
- [14] Mosavi, M. & HekmatNia, h., the factor analysis and the combination of indexes in determine the effective factors on the development of human in the areas of Iran, autumn and winter, Journal of Geography and Development, 2005. Pp. 55-70.
- [15] Group GMI6. The educational Series statistical analysis in survey research by SPSS PASW software, trial version 2, 2011.
- [16] [www.gmi6.com/.../s5-factor-analysis-varimax.html](http://www.gmi6.com/.../s5-factor-analysis-varimax.html)
- [17] <http://rah-jkerman.ir/83-2015-10-08-08-39-08/104-20>.

**Appendix 1:** Questionnaires for factors analysis safety in road and pavement repair and maintenance

Please complete the following questionnaire with specific regard to the above enquiry, by placing a **CROSS** in the appropriate box

Row	Statements	strongly agree	agree	not applicable	uncertain	disagree	strongly disagree	no comment
1	The length of work zone range effects on increasing the number of crashes.							
2	run at night hour due to low light cause to increase accidents							
3	Run in the heat of the day cause to increase the number of accidents.							
4	Speed vehicles reduced when workshop area has the proper signs.							
5	Large width of the work zone bothering drivers, they faced with more events.							
6	Deceleration and driver's detained within the work zone cause to fatigue more drivers and the increase of accidents.							
7	Crossing truck and heavy vehicles in comparison with light vehicles and car cause to increase more accidents.							
8	The most injuries in pavement repair work within the area that faces in the traffic flow direction, like flag-man.							
9	The best tools to protect the safety of workers within the scope of pavement road are to use the solid & stable barriers.							
10	The best way to protect the safety of workers in the scope of pavement road is to use the traffic police.							
11	11 use of new machinery cause to reduction of accidents within the workplace.							
12	Use of personal protective clothing and safety has a great effect on the safety in the area of work zone road pavement repair and road.							
13	Whatever the rate of pavement failure and workload is more, the probability of occurring incidents will be more for workers.							
14	Run at day due to the sufficient light caused to increase the rate of volume the repair and maintenance operations.							
15	run at day hour with favorable weather, cause to increase the rate of efficiency and the volume of operation							
16	Work at night hour due to the less vehicles cause to increase the efficiency of work and the maintenance operations.							
17	The use of machineries and technology and new materials has the most effects in increasing the efficiency and volume of carried out operations.							
18	The large width of work zone area causes to increase the rate of efficiency of labor and increases the operations of maintenance.							
19	The division of work zone to smaller area is better than a large and long range.							
20	Within the workshop, the most damaging factor to the workers is the smoke of vehicles.							
21	Within the workshop, the most damaging factor to the workers is the noise of passing vehicles.							
22	Within the work zone the most annoying factor to the workers is the dust and particulate matter air.							
23	Severe controls can reduce the amount of pollution in the executive environment, pavement maintenance.							
24	The use of new machines and new materials in repairing the pavement in reducing air pollution and smoke has the most effect.							
25	The use of machineries and technology and new materials has the greatest effect in reduction of noise pollution.							

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..... Thank you for your help