IMPLEMENTATION OF FACTOR ANALYSIS IN PROJECT OF LIGHTING SYSTEM MODERNIZATION

Tatjana Atanasova-Pacemska
Faculty of Electrical Engineering, University "Goce Delcev", P.O. Box 201, 2000 Stip, Macedonia, e-mail: tatjana.pacemska@ugd.edu.mk

Vasilija Sarac
Faculty of Electrical Engineering, University "Goce Delcev", P.O. Box 201, 2000 Stip, Macedonia, e-mail: vasilija.sarac@ugd.edu.mk

Abstract

Factor analysis refers to a method of variable analysis used for description of mutual correlations of great number of variables, mutually interconnected and influenced by different factors. Numerous tests with lot of questions are used in the process of research. Factor analysis is developed on the base of obtained test results aiming towards reduction of number of variables in case when they are overlapping or have similar meaning or behavior. In this case, factor analysis is implemented in project of modernization of lighting system in municipality of Kocani, R. Macedonia in order to obtain complex study of all relevant factors, which have influence on cost savings, improvement of the quality of the lighting system and their mutual correlations. Factor analysis is performed in software program Minitab, implemented on three different scenarios regarding modernization of lighting system. In all three scenarios, up to six variables are evaluated with respects to the different factors, which have strong influence on them. Based on obtained values of the correlation factors adequate conclusions are derived enabling cost effective solution of overall projected to be achieved.

Keywords: *correlation factors, factor analysis, financial analysis, modernization of lighting system*

INTRODUCTION

Factor Analysis is one of the most popular multivariable techniques, which have two main goals: identification of basic idea or common characteristic of more variables and decreasing the number of variables, which are similar and have significant interconnection. In interconnection techniques, there is no strict division on dependable and undependable variables as in fact all variables are undependable. These techniques are searching for a model of correlation among variables, which has a meaning from the point of view of the specific problem research. In order factor analysis to be used on efficient way there should be a minimum quantity of redundant variables or variables should at least little overlap in their meaning [1]÷[2]. Due to this redundancy, there is a possibility to discover a pattern in variables' behavior or to discover the main idea (factor) which connects them. Factor loading is the coefficient of correlation between each variable (characteristic) and the factor itself. The greater the correlation is, the given characteristic (variable, question) is better describing the given factor [3]. Choice of the proper solution based on the analysis of the factors, which have influence on the process of the decision-making, has a wide implementation in project implementation. In this paper project of modernization of lighting system in municipality of Kocani is analyzed in order to obtain complex study of all relevant factors, which have influence on cost savings, improvement of the quality of the lighting system and their mutual correlations. Factor analysis is performed in software program Minitab, implemented on three different scenarios with respect to the modernization of lighting system: scenario no.1- financial analysis, scenario no.2- choice of the type of the lighting and scenario no.3- survey among citizens of municipality Kocani regarding different aspects of lighting system in their municipality. In all three scenarios, up to six variables are evaluated with respects to different factors, which have strong influence on them.

METHOD OF FACTOR ANALYSIS

IMPLEMENTATION OF FACTOR ANALYSIS IN DECISION MAKING THEORY

Choice of proper solution and analysis of factors, which have influence on process of decision-making, has implementation in every project. It is based on evaluation of mutual correlations of data and their influence on the project implementation. Characteristics that are important in process of data analysis are:

1. Importance of decision- factors that influence how the decision is made and what method of analysis will be implemented in process of decision-making.
2. Time and costs regarding decision making-time within the decision is reached, should be followed by minimum costs, considerably smaller than the project value.
3. Analysis of the complex solution- within decision reaching process, analysis should be performed by taking into consideration following steps: large number of variables should be used for analysis and comparison, usage of strictly correlated variables and exclusion of uncompleted data.

In order, proper solution to be achieved following six steps should be taken into account:

1. Problem setting – in our case study increased amount of financial expenses for street lighting system in the municipality of Kocani, old type of lighting, decreased quality of lighting on some parts of the streets.
2. Problem definition - replacement of old type of lamps with the new ones in order quality of lighting to be improved.
3. Decision criteria- financial costs, choice of the type of the lamp, period for replacement
4. Alternative solutions – adequate armatures for the lamps, which can serve as replacement of the existing ones. Replaced armatures can be from different type from the existing ones.
5. Data analysis – analysis of gathered data from field acquisition, costs calculation, percentage of utilization of substations.
6. Decision making-choice of the most favorable solution, which will improve actual situation.

Important phase in decision-making is implementation and usage of model, which will eliminate problems that occur during the analysis. Most commonly, this model is represented by a matrix, which can determine the efficiency of the certain solution.

Table 1. Decision matrix

Alternatives	Existing solutions	Existing solutions
A1	E11	E12
A2	E21	E22
A3	E31	E23
Am	Em1	Em2

Factor analysis is used in order to be presented the best adequate solution that can be implemented because of decisions making process. Actual situation regarding project of modernizations of lighting system in municipality of Kocani is presented in Table 2.

Table 2. Actual situation of lighting system

Alternative	Solution	Actual situation
A1	Replacement of lamps	Mercury lamp 125 W
A2	Replacement of lamps' armatures	Mercury lamp 250 W
A3	Implementation of control system	Economical lamp

Possible alternative solutions, which can be implemented in process of decision-making, are presented in Table 2. Last column from Table 2 is presenting the actual situation in municipality of Kocani. Three types of lamps are used for city lighting: mercury lamp 125 W and 250W and economical lamp. Any of the alternatives can be chosen as possible solution in modernization of lighting system but attention should be paid that lamps or armatures should be replaced first before implementation of control system. Most commonly, apriori algorithm is used for data analysis and choice of most optimal solution.

METHOD OF FACTOR ANALYSIS IN DATA EVALUATION

Factor analysis as well as other statistical methods is used to find the proper number of adequate variables, which are implemented, in decision-making process. It is especially useful in identification of data structure i.e. variable classification and their reduction [4]. Main purpose of the factor analysis is to gather information contained in great number of

variables into smaller number of factors while maintaining minimal loss of information as well as to achieve better understanding of correlation among variables. It is assumed that all variables within certain group are highly correlated and in the same time they are very little correlated with the variables from the other groups. Then each group of variables can represent one factor. For proper implementation of factor analysis in data analysis, following three steps should be implemented :

1. Definition of correlation matrix-matrix with coefficients, which are representing the correlations among data.
2. Selection and choice of variables – defining the type of the variable.
3. Ratio between variables and factors should be 10 to 1.

Analyst should try to reduce the number of variables and to keep the reasonable number of them per factor. At least five variables should represent certain factor. Analyst must also ensure that correlation matrix has sufficient number of correlations in order factor analysis to be implemented. In case of modernization of the lighting system factor analysis is implemented in Minitab software developed at Pensilvania State University in 1972, today commercially available. Complete factor analysis is performed for three possible scenarios: scenario nr.1 – financial analysis, scenario nr. 2- choice of type of lamps and lamps' armature and scenario nr. 3 – citizens' opinion.

RESULTS FROM FACTOR ANALYSIS

SCENARIO NR.1- FINANCIAL ANALYSIS

In this scenario, ten streets with ten variables are analyzed. Mentioned variables are:

V1. Financial cost regarding lamp replacement (lamp price)
V2. Financial costs due to replacement of operational equipment
V3. Quality of street lighting and usage of financials for its improvement
V4. Costs regarding implementation of computer system for light control and coordination
V5. Costs per street in city area-municipality of Kocani
V6. Usage of financials for improvement of traffic lightening
V7. Frequency of people
V8. Additional expenses
V9. Pay off of invested financials
V10. Actual financial gain (current situation)

Table 3 Characteristics of variables per streets-correlation matrix

	V1	V2	V3	V4	V5	V6	V7	V8	V9	V10
1.	4	5	4	5	5	5	5	3	5	4
2.	5	5	4	5	5	5	5	3	5	4
3.	5	5	4	5	5	5	5	4	5	4
4.	4	5	3	5	5	5	4	3	5	4
5.	5	5	4	4	4	4	4	3	4	3
6.	3	4	3	4	4	4	3	4	3	3
7.	3	3	3	4	4	4	3	4	4	3
8.	2	4	4	3	3	3	3	5	3	4
9.	1	2	4	3	4	3	3	5	2	1
10	3	3	3	3	3	3	3	4	3	3

In Table 3 all these variables and their characteristics are evaluated and certain number is assigned to each variable in range from 1 to 5 where 1 represents the minimal costs and 5 is the maximal. All these variables are assigned to ten streets. Choice of the streets is random. Above mentioned ten variables are grouped under four factors which represent the main characteristics of the group of variables. In this scenario factors are:

- Financials and their distribution-factor 1
- Population and frequency of movement-factor 2
- Maintenance of the system for street lightening-factor 3
- Improvement of current situation and implementation of computer system-factor 4

After factor analysis is run in Minitab program factor coefficients are obtained in correlation to six variables. Some redundant variables are grouped under one variable so the total number of variables is decreased. In Table 4 are presented correlation coefficients regarding above-mentioned four factors.

Table 4. Factor Score Coefficients - scenario nr. 1

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Price	-0.430	-1.228	0.082	-1.594
Quality	-0.118	0.090	-0.895	0.100
Expenses	0.942	0.433	0.055	-0.939
Traffic	0.429	0.106	0.149	0.049
Population	0.062	-0.110	-0.283	0.260
Pay off	-0.193	0.025	0.062	2.464

From presented results in Table 4, it can be concluded that price and financial costs for

lamp replacement are depending from factor 2, which is population and frequency of movement. Payment of all financial bills for street lighting in areas, which are densely populated, contributes towards gathering of considerable amount of financials that can be used for on time replacement of lamps as well as for their proper distribution. In this case factor coefficient is negative but it has the highest value -1.228. Quality of the street lighting mostly depends from factor 3- maintenance of the system for street lighting. If lamp replacement is on time and maintenance activities are scheduled and carried out on time than consequently the quality of street lighting will be improved. Factor coefficient is negative but with highest value -0.895. Expenses of street lighting are dependent on finical and their distribution. In case of sufficient financials maintenance activities are carried out regularly which actually decreases the expenses for street lighting. If there is a financial gain, expenses will not overload municipality budget. Also in this analysis factor coefficient is positive and has the highest value 0.942. As it can be seen form Table 4 traffic and quality of lighting as well as improvement of visibility in night hours is highly dependant from financials and their distribution. Improvement of the quality of the lighting contributes towards increased safety in traffic so it very important segment in municipality budget. Here factor coefficient is also positive and has the largest value 0.429. Maintenance of the street lightening is in close connection with the density of the population. In case of larger financials, which are dependant on the density of the population maintenance activities can be carried out on more frequent base. Here factor coefficient is -0.283. Computer system for light control and coordination has influence on pay off of invested financials since it can decrease the costs for maintenance activities, provides cost and energy savings and speeds up the complete process of pay off. Consequently, factor coefficient which correlates the pay off of financials with computer system is the largest and its value is 2.464. Regardless of the sign of factor coefficients, coefficients with largest values are taken into consideration.

SCENARIO NR.2-CHOICE OF LAMPS AND LAMPS' ARMATURES

In this scenario, also ten variables, which characterize the lamps, are analyzed. Characteristics of the lamps are following:

1. Price and financial gain/lost from lamp replacement
2. Replacement and duration of lamps and lamps' armatures
3. Lamp model and its usage
4. Quality of lighting
5. Usages of lamps in the area of the municipality
6. Operational life of the lamp
7. Additional expenses during operation
8. Implementation of lamps
9. Heating during operation
10. Radiation during operation

Following types of lamps and lamps' armatures are analyzed: mercury lamp of 125 W and 250 W, economical, LED, fluorescent and metal halogen. Again, matrix for factor analysis is formed similar to the one in Table 3 and for the purposes of factor analyses above mentioned ten variables are reduced to six variables grouped under four factors:

- Implementation of lamps-factor 1
- Warranty-factor 2
- Type/model of lamps' armature with respect to different types of lamps-factor 3
- Financial savings during replacement of lamps –factor 4

Results from factor analysis after software program Minitab is run are presented in Table 5.

Table 5 Factor Score Coefficients - scenario nr. 2

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Model	-0.331	-0.025	0.248	1.584
Quality	0.049	0.597	0.981	-0.221
Usage	-0.325	0.144	-0.158	1.409
Operational life	0.196	0.475	-0.844	1.477
Implementation	0.284	-0.296	0.523	2.475

Obtained results in Table 5 can be interpreted on following way: model of the lamp and its choice is dependant on financial savings. If the municipality has enough financial resources, it can be expected that lamps will be replaced on time with adequate models. Sufficient founds

enable usage of lamps with better quality from reputable producers and consequently they have better performances than lamps, which are actually in usage in municipality. Here factor coefficient, which relates model of the lamp with financial savings, has the largest value of 1.584. As one can expect quality of lighting is highly dependent on the type (model) of the lamp and the lamp's armature. High quality producers offer lamps with better characteristics and they have influence on the quality of the lighting. Therefore, in this case the factor coefficient between variable "quality" and factor "type/model of lamp and lamp's armature" has the highest value 0.981. Usage of lamps and lamps' armatures is dependant on financial savings and available financials in municipality budget aimed for public lighting. If there is a shortage of financials, it can be expected that replacement of lamps will go slowly and consequently their usage will be postponed. This correlation is represented by factor coefficient of 1.409. Correlation of the operational life of the lamp and financial resources is evident as lamps with better performances, which might be more expensive, have also longer operational life. Sufficient financials enables usage of lamps with better performances and consequently longer operational life. Implementation of lamps is again highly dependant on available financials and in this case, factor coefficient has value of 2.475.

SCENARION NR.3-CITIZEN'S OPINION-SUVEY

Last scenario, which is analyzed within this project, includes survey of public's opinion in municipality Kocani. Ten questions are asked among twenty citizens with respect to the lighting in the municipality. Again, evaluation of answers and citizen's opinion as in the previous scenarios is awarded with marks from one to five. Public opinion regarding modernization of lighting system is very important since financials are gathered from citizens and they are the end users of lighting system so their opinion plays an important role in whole project realization. Following questions (Q1-Q10) have been asked:

Q1: Are you satisfied with public lighting within municipality of Kocani?
Q2: How you are satisfied with the services of the team who works on maintenance of the system for public lighting?
Q3: Are the expenses for public lighting acceptable?
Q4: Does public lighting contribute towards pollution?
Q5: How do you evaluate the distribution of public lighting within the municipality?
Q6: Is the traffic lighting on satisfactory level?
Q7: How do you evaluate lighting in city center?
Q8: Is there too much electricity consummation for street lighting?
Q9: Is there necessity for modernization of lighting?
Q10: Is there a need of computer system for light control and coordination?

After factor analysis is run six variables are grouped under three factors:

- Human factor-factor 1
- Financial factor-factor 2
- Quality of lightening-factor 3

Results from factor analysis are presented in Table 6.

Table 6 Factor Score Coefficients - scenario nr. 3

Variable	Factor 1	Factor 2	Factor 3
Q3	0.232	0.489	-0.341
Q5	-0.381	0.395	0.321
Q7	0.221	0.371	0.685
Q9	0.328	-0.354	0.509
Q10	0.501	0.143	-0.324

According to the results presented in Table 7 expenses for street lighting and their decreasing or controlling depend on financial factor-budget which is available at municipality and its proper distribution. In this case, correlation factor is 0.489. Distribution of public lighting within the municipality depends on available financials, if there is sufficient financials than all areas should be satisfactory lightened. Factor coefficient is 0.395. On the other hand, it is recommendable central city area to have the highest quality lighting since there is large frequency of people and vehicles in the central city area. Factor coefficient is 0.685. According to the citizens of municipality Kocani it is necessary lighting system to be modernized in order to be improved quality of life within the municipality. Factor coefficient in this analysis

is 0.509. According to the results in Table 6 implementation of computer system for light control and coordination depends on human factor. Survey among citizens regarding implementation of computer system is recommendable in order to obtain citizens' opinion regarding this subject. Factor coefficient in this case is 0.501.

CONCLUSION

Decentralization of local government in R. Macedonia has increased the responsibilities of each municipality. Modernization of lighting system is one of the projects, which have immerged in municipality of Kocani as a priority of the local government. Extended research and preparatory works are done with respect to data gathering from field and their classification. Modernization of the lighting systems covers mainly three wide areas: replacement of lamps, replacement of lamps' armatures and introduction of control system for light control and coordination. Decision making in every project is a complex task and it is influenced by different factors. Therefore, factor analysis is implemented in order different variables that are influenced by different factors to be evaluated. The strength of correlation between project variables and factors is expressed by factor coefficients. The bigger the value of factor coefficient is, the stronger its correlation with factor is. Three different scenarios are evaluated with respect to different project variables: scenario nr.1 – financial analysis, scenario nr.2- choice of lamp model and light armatures and scenario nr.3- citizen's opinion-survey. First scenario has showed that there is a strong correlation between expenses and available financials. In case of sufficient financials maintenance activities are carried out regularly which actually decreases the expenses for street lighting. If there is a financial gain, expenses will not overload municipality budget. Strong correlation is noticeable between pay off of invested financials and implementation of system for light coordination and control. Implementation of computer system decreases the costs for maintenance activities enables cost and energy savings and speeds up the complete process of pay off.

In scenario nr. 2 there is a strong correlation between model of the lamp, its usage, operational life and implementation in correlation to the available financials. As one can expect models from reputable producers can be more expensive but they have longer operation life, better performances, longer warranty period, energy saving costs and in long-term period, they enable financial savings.

According to the scenario nr.3 and conducted survey among citizens there is a need for improvement of the quality of the lighting and for implementation of computer system for light control and coordination. The letter one should improve the quality of lighting and speed up the maintenance activities since it enables overview of lighting in the city with all occurred faults, which makes the lamp replacement easier and cost effective.

Paper has proved that this statistical method has useful implementation in practical project realization. It creates a bridge between theory and practice, proving itself as a useful analytical tool for project evaluation.

REFERENCE

[1] S.Hassan, N. Ismail, W. Y. W. Jaafar, K. Ghazali, K. Budin, D. Gabda and A. S. A. Samad, "Using Factor Analysis on Survey Study of Factors Affecting Students' Learning Styles", International Journal of Applied Mathematics and Informatics, Vol.6, No.1, pp. 33-40, 2012.

[2] C. Allison, S. Baron-Cohen, M. H. Stone, S. J. Muncer, "Rasch Modeling and Confirmatory Factor Analysis of the Systemizing Quotient-Revised (SQ-R) Scale", Spanish Journal of Psychology, doi:10.1017/sjp.2015.19, 2015.

[3] N. Dehak, P. J. Kenny, R. Dehak, P. Dumouchel, P. Ouellet, "Front-End Factor Analysis for Speaker Verification", IEEE Transactions on audio, speech, and language processing, Vol. 19, No. 4, pp. 788-789, 2011.

[4] B. Williams, A. Onsman, T. Brown, "Exploratory factor analysis: A five-step guide for novices", Journal of Emergency Primary Health Care, Vol. 8, Issue 3, pp. 1-13, 2010.