# International Journal of Engineering Technologies (IJET)

**Volume:7**
**No:2**
**June 2021**

**Printed ISSN: 2149-0104**
**e-ISSN: 2149-5262**

*International Journal of Engineering Technologies is an international peer–reviewed journal and published quarterly. The opinions, thoughts, postulations or proposals within the articles are but reflections of the authors and do not, in any way, represent those of the Istanbul Gelisim University.*


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**Printing and binding:**
Anka Matbaa
Certificate Number: 44889
Phone: +90 212 5659033 - 4800571
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**INTERNATIONAL JOURNAL OF ENGINEERING TECHNOLOGIES (IJET)**
**International Peer–Reviewed Journal**
**Volume 7, No 2, June 2021**

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## From the Editor

Dear Colleagues,

On behalf of the editorial board of International Journal of Engineering Technologies (IJET), I would like to share our happiness to publish the 26th issue of IJET. My special thanks are for members of Editorial Board, Publication Board, Editorial Team, Referees, Authors and other technical staff.

Please find the 26th issue of International Journal of Engineering Technologies at http://ijet.gelisim.edu.tr or https://dergipark.org.tr/en/pub/ijet. We invite you to review the Table of Contents by visiting our web site and review articles and items of interest. IJET will continue to publish high level scientific research papers in the field of Engineering Technologies as an international peer-reviewed scientific and academic journal of Istanbul Gelisim University.

Thanks for your continuing interest in our work,

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**Printed ISSN: 2149-0104**
**e-ISSN: 2149-5262**


International Journal of
Engineering Technologies
IJET

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**Volume 7, No 2, June 2021**

**International Journal of Engineering Technologies, IJET**

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# Design of a System Dynamics Model (SDM) to Evaluate the Supply Chain of Biological Products

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*Received: 17.11.2020 Accepted: 28.05.2021*

**Abstract-** Today, organizational agility in a competitive business environment has become the primary principle of success. In the supply-chain management of any organization, its suppliers play an important role in achieving this significant goal. Therefore, the importance of evaluation in selecting and cooperating with suppliers plays a noteworthy role in increasing the chances of success. Meanwhile, identifying the supplier's evaluation indicators in a dynamic and uncertain environment has become a major challenge for managers. This article tries to provide an accurate and reliable solution to this important challenge based on the design of a System Dynamics Model (SDM). Thereby, the main purpose of this paper is to provide a model for evaluating suppliers in the biological supply chain. Then, the reliability and accuracy of the proposed model, are evaluated with several statistical tests. Finally, the performance of this model is shown in the supply chain of a vaccine and serum Institute. The results obtained, both in the tests and in the case study, all indicate the model's ability, reliability, and high accuracy in evaluating suppliers.

**Keywords-** System Dynamics Model; Biological Supply Chain; Supplier Evaluation System, Cause and Effect Diagram, Stock-Flow Diagram**.**

## 1. Introduction

Rapid and unavoidable changes in today's world due to the phenomenon of globalization and the headlong advancement of science in economic, political, and industrial dimensions -especially in the last two decades- have led to dramatic technological developments within the field of information and communication. The speed and acceleration of these changes in different dimensions have led managers to improve the internal processes of organizations in order to maintain the survival power in a market that is becoming more competitive every day [1]. In today's global competition, it is necessary to make a variety of products available to customers according to their requirements. Customer expectations of high quality and fast service have increased the pressure on companies that did not exist before. Therefore, companies cannot independently meet all customer needs and expectations [2]. Therefore, in addition to overseeing their internal affairs, organizations need to focus on managing and evaluating matters outside the organization. The main goal of this issue is to achieve competitive advantages to gain more market shares [3].

With the increasing complexity of information, the strategic focus of companies is constantly changing. Therefore, the competitive environment in this market is inevitable. Many active companies acknowledge that today's competition is, in fact, competitive in the supply chain and that the focus on supply chain management will be the most important source of competitive advantage [4]. Therefore, the fundamental role of suppliers in improving the performance of the supply chain has made it important to identify the criteria for ranking and selecting suppliers [5,6].

Today's past production management models, which have been less integrated into their processes, have lost their effectiveness, and integrated supply chain models as a harmonic approach to the proper management of materials, goods, information, and finance have the ability to respond to conditions[7]. As organizations become more dependent on suppliers, the direct and indirect consequences of wrong decision-making become more detrimental. The globalization of trade and the growing expansion of the Internet has

increased the variety of supplier selection techniques. Acquiring customer satisfaction, meeting customer needs, and priorities requires a prompt and appropriate selection of suppliers [8]. New organizational structures have led to more people being involved in decision-making to select suppliers, and therefore, the position and value of decision-making have increased [9]. The complexity and importance of decision-making in selecting suppliers clearly illustrates the need for a clear and transparent approach. Improper choice of suppliers can disrupt the financial and technical position of a supply chain [10]. Due to the increasing interest of companies in strategic cooperation with key suppliers during the product-development process, the team responsible for selecting suppliers must use tools to be able to classify suppliers based on their capabilities and performance. Many successful companies believe that selecting a supplier is one of the most important activities of organizations [11]. Therefore, choosing the right supplier in chain management is a challenging issue. Meanwhile, in the supply chain of biological products, in order to provide timely and quality materials, this issue is of special importance in the field of planning, control, and evaluation [12]. Given the importance of this issue and the fact that in recent years, the industry of production of biological products has undergone many changes, the most important of which is the globalization of markets, changes in technology, changes in customer needs and reduced product life cycle, besides, the key role of suppliers in improving this chain led to the issue of selecting suppliers by identifying the most important criteria in dynamic environmental conditions in this study.

Considering that strategic cooperation with suppliers is necessary to provide high-quality materials and reduces the delivery time of the projects in the Razi Vaccine and Serum Research Institute (RVSRI), it seems essential. Therefore, one of the goals of this Institute in a competitive environment is to provide quality requirements promptly and at a reasonable cost according to other performance indicators. Given this, the selection of suppliers has had a significant impact on achieving these goals, and this process is critical to the success of RVSRI. It should be noted that the greater dependence of RVSRI on its suppliers could have irreparable consequences for this institution. The high cost and sensitivity of the materials and equipment required, as well as the need for global standards, on the one hand, and the importance of their timely delivery on the other, make the process of selecting suppliers more sensitive and require more precision. Creating a dynamic decision-making system under the characteristics and feedback of suppliers based on the

Indicators of the Razi Institute is one of the main goals of this organization. Despite much research into the evaluation and selection of suppliers, the Institute continues to suffer from a lack of system dynamics (SDs) in various fields. Especially in Razi Institute, considering the huge volume of purchases and their preparations and sensitivity, as well as the uncertainty in parameters and variables, the evaluation and selection of suppliers of the Institute based on the SDM are very important and vital. Therefore, in this study, the simulation of a dynamic system has been used for modeling to evaluate suppliers in the Razi Institute. The purpose of this paper is to achieve a general strategy in evaluating and selecting providers of the Razi Institute and to provide a model in dynamic conditions.

The results of the dynamic system model with integration of qualitative and quantitative metrics are designed to evaluate the interaction and relevance of factors that some of them may conflict even with each other. The model structure is designed to be considered among the suppliers, so that if any of the suppliers face the risk, they may act to cause changes and improve their performance. Considering the four suppliers and parameters associated with them, which consists of 16 criteria, compared to suppliers in different time periods, the results from the dynamic system model results in ranking and supplier selection. Finally, after simulation, the validity of the model was investigated by several tests including boundary sufficed test, structure evaluation test, boundary conditions test and integrity test, which confirmed the results obtained from the dynamic system model.

## 2. Methodology

The methodology of this research, from the goal perspective, is in the category of applied research, in terms of how data is collected, is in the category of descriptive (non-experimental) research and finally, in terms of implementation, falls into the category of survey research. In this paper, an attempt is made to provide a model for evaluating the suppliers of a health supply chain in the biological industry using SDs. The main data of this article have been collected through direct interview and questionnaire.

### *2.1. Method of Data Analysis*

In this paper, using the SDs analysis technique, the initial behavior of the effective variables in the evaluation of the providers of the Razi Institute has been performed. Then, causal relationships between the main and secondary factors based on the two techniques of cause and effect diagram and Stock-Flow Diagram have been determined in the SDs approach. The reliability and validity of the proposed model are examined using simulation in VENSIM software. Finally, different scenarios are defined for Razi Institute and by implementing the mentioned model in each scenario, the effects of different decisions on the cost and income of the

Razi Institute in a certain period of time are determined, and the best scenario is selected.

## 3. System Dynamics Modeling (SDs)

Modeling is a process of feedback, and models are created by performing a series of constant repetitive processes, sequential questions, testing, and optimization. The modeling process is not a very clear process, and it is not possible to prescribe clear steps for all dynamic processes in the same way. In the modeling process, each model maker has different approaches; However, all successful models follow a regular process that includes the following activities:

1. Creating a framework for the problem (System boundary)
2. Create a dynamic hypothesis about the causes of the problem
3. Formulate a simulation model to test a dynamic hypothesis
4. Test the model
5. Design and evaluate policies to improve [13].

Figure 1 shows the modeling process in more detail. The main art of modeling with the SDs is to discover and introduce feedback processes, which, together with the Stock-Flow diagram, determine the time delays and dynamics of a system, and it helps identify system structural defects.

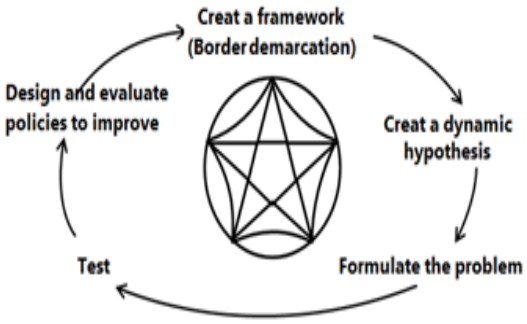


**Fig. 1**. The main steps of the modeling process

### *3.1. System Boundary*

Each system has a boundary that separates it from its surroundings and at the same time connects it to the environment. It can be said that the boundaries of the system are points beyond which the specific features of the system are no longer recognizable. Perhaps if the boundaries of the system are broader, the facts will be much clearer and better understood; However, it should be noted that sometimes expanding the boundaries of the system creates complexities that make it difficult to solve the problem. The model boundary is not predetermined and is determined by the researcher[14].

**Table 1**. System boundary

| **Level** | **Indicator** | **Variable type** |
|---|---|---|
| **Product** | Price | Exogenous |
| | Quality | Endogenous |
| | Variety of production line | Exogenous |
| **Service** | Reliability of product delivery | Endogenous |
| | Supplier obligations | Endogenous |
| | Registered business experiences | Exogenous |
| **Risk** | Trade restrictions | Exogenous |
| | Perception and acceptance of risk | Exogenous |
| **Supplier background** | Documents | Exogenous |
| **Cost** | Ability to reduce costs | Endogenous |

In this study, different indicators such as product type, supplier services, etc. have been considered to evaluate suppliers. Hence the system boundary is given here in the form of T able 1. In a way, this boundary of the system represents the scope of the model by identifying and categorizing endogenous and exogenous variables at each level An exogenous variable is a variable whose value is determined outside the model, and a change originating within the model boundary means a change in an exogenous variable. In contrast, an endogenous variable is a variable whose value is determined by the model itself. An endogenous change means a change in an endogenous variable in response to an exogenous change that is imposed upon the model.

As shown in the table, here the system boundary is defined in five levels of product, service, risk, supplier background, and cost, considering the factors such as price, quality, supplier obligations, etc. and other factors are ignored. It should be noted that at each of the levels, several factors were examined, and finally by using the questionnaire and the experts opinion of the mentioned indices.

After identifying the purpose and boundaries of the system, the factors affecting the key variables of the problem must be identified. What variables are effective in evaluating suppliers? In what position and rankings does each supplier have compared to its competitors? What is the status of each supplier in the short and long term? Evaluating suppliers is one of the challenges facing any organization. The

dependence of this problem with the identification of activities, products, and information requires that the factors involved to be examined. Especially when the researcher needs to be aware of how these factors will affect the long-term or short-term evaluation process to make decisions or make changes.

### *3.2. Modeling*

Feedback is the process by which a variable in a series of cause-and-effect relationships, interacts with other variables. There are two types of causal relationships in this regard: [13]

- Positive cause and effect relationship (+): Changing the cause in one direction effect on another variable to change in the same direction (Figure 2a).
- Negative cause-and-effect relationship (-): Changing the cause in one direction effect on another variable to change in the opposite direction (Figure 2b).

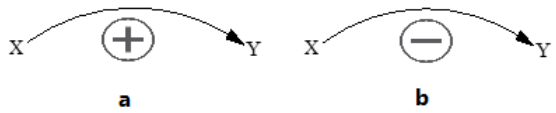


**Fig. 2**. Positive and negative causal relationship

In this regard, the connections between the components of the system are not linear and are in the form of cause and effect loops. There are two types of loops: Positive (reinforcing) and negative (balancing) loops; A small change in one of the variables within the loop must be traced to determine whether the loop is negative or positive. If the feedback exacerbates the initial change, the loop is positive, and if it is the opposite, the loop is negative. The symbols used for positive and negative loops are as follows (Figure 3):

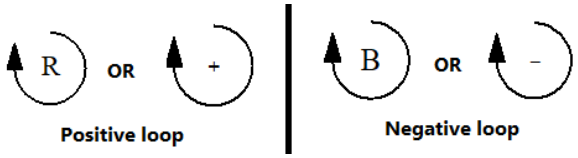


**Fig. 3**. Feedback loops

### *3.3. Cause and Effect Diagrams*

The SDs use a variety of graphical tools to understand the structure of a system, such as cause-and-effect and Stock-Flow diagrams. A cause-and-effect diagram is an important tool for showing the feedback structure of systems [13]. The most important applications of this diagram are the following:

- Quick access to hypotheses about the causes of dynamics
- Inference and understanding of the mental models of individuals or groups
- Investigating the relationship between important and influential feedback on model performance

Drawing loops and conceptual connection between variables is one of the most important steps in building SDMs. First of all, it should be noted that the performance of each supplier and the ability of each to meet the demands of the organization are determined and evaluated by different factors. Furthermore, the interaction between these indicators can reduce or increase each of them. On the other hand, it is obvious that each of the suppliers does not act individually and is competing with each other and trying to increase its success in meeting the expectations of the organizations. By considering the indicators related to each of the suppliers, the organization tries to select the best supplier according to the goals within the organization and according to it, it tries to formulate its strategies. For example, if two suppliers are evaluated by the experts of the organization and their performance is ranked and scored by different indicators, it is obvious that the demand for purchases from suppliers with higher scores will increase. This will create competition for suppliers who offer the same or similar products. So the two companies are competing to gain more market share. Therefore, if the performance of the supplier number one increases, the demand will increase and it will stimulate the competition of supplier number two. As competition increases, supplier No. 2 will seek to improve its performance. With the increase in the level of performance of supplier number two, the demand for it will increase and the competition of supplier number one will increase. As competition increases, the level of performance of supplier number one increases again. The reinforcing loop of the model with four suppliers is shown in Figure 4.

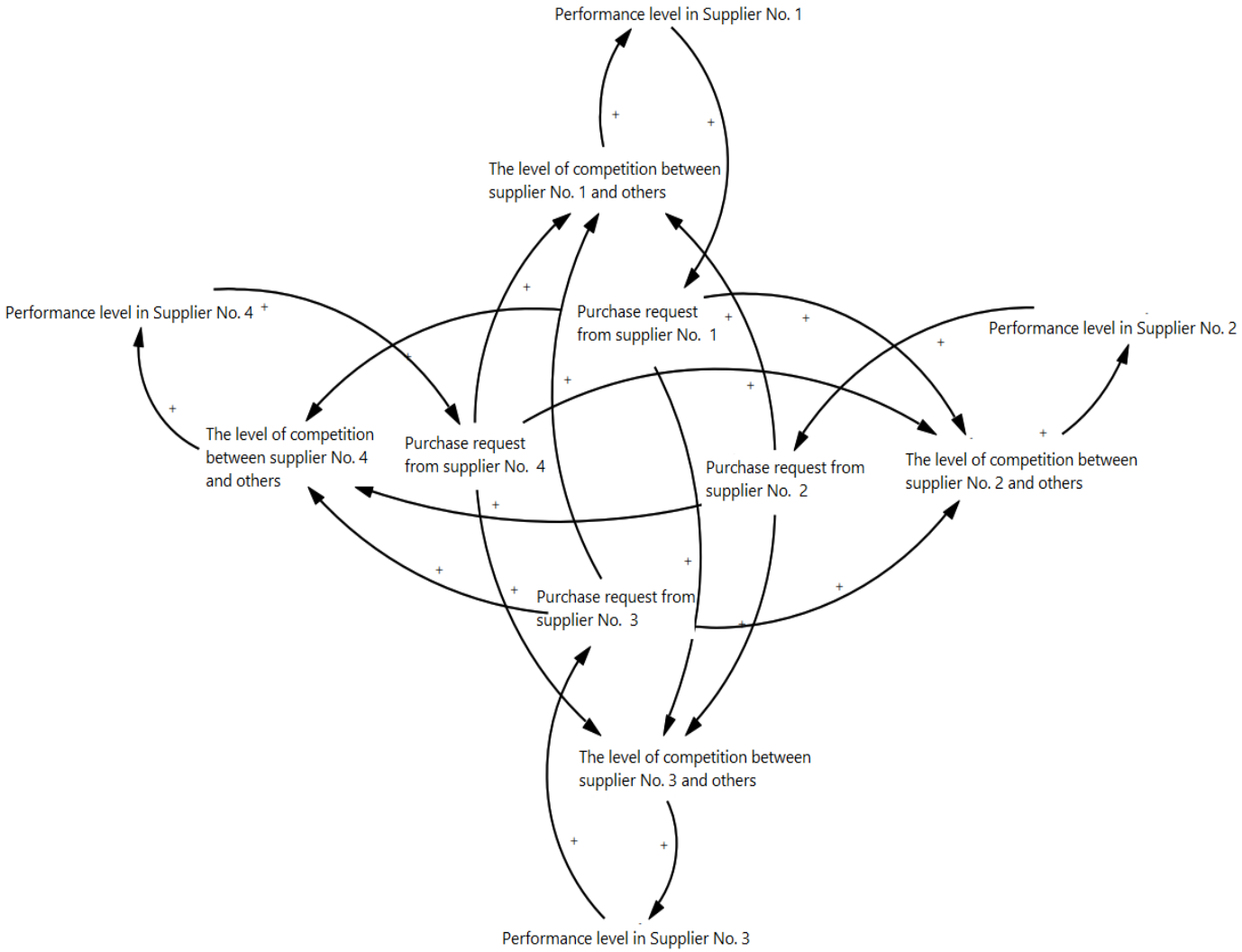


**Fig. 4.** The reinforcing loop in the model (with four suppliers)

Moreover, increasing the level of performance of suppliers Note that increasing the demand for each supplier will affect the competitiveness of other suppliers and their performance. Moreover, increasing the level of performance of suppliers will lead to more demand from the organization, which will automatically increase the income of the supplier and will lead to more profitability. By increasing profits, the company will increase the quality of its product and the high quality of the product will improve the performance of the supplier. Figure 5 shows this part of the model.

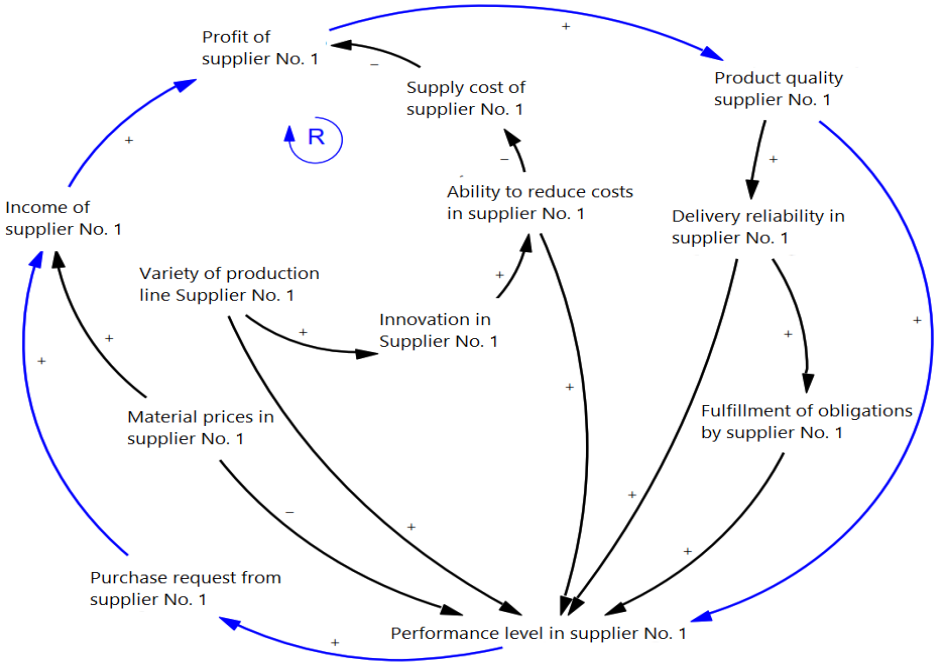


**Fig. 5.** The cause and effect loop that reinforces the supplier's profit

By improving product quality, the supplier will deliver more reliable products to the applicant, which will enable the supplier to perform better on its obligations to the organization and increase its performance by increasing its credibility. This part of the model is shown in Figure 6.

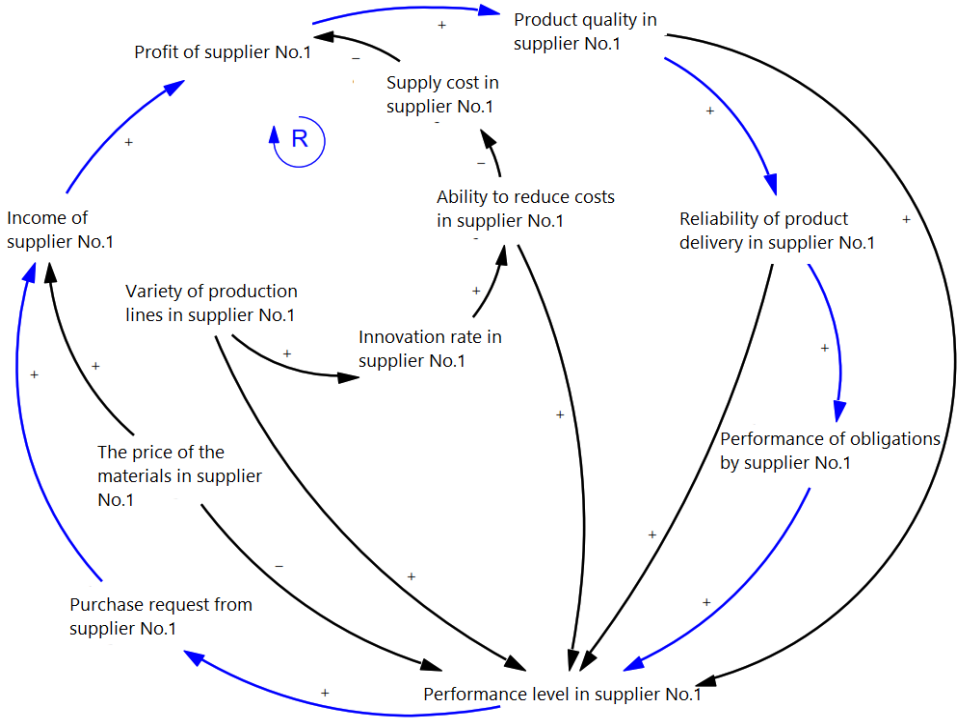


**Fig. 6.** Cause and effect loop related to supplier commitments

As mentioned earlier, to simplify the cause-and-effect model, the model is shown in different sections for a supplier. In cases where the suppliers were similar in terms of the factors under consideration , the other suppliers will act as mentioned above However, it should be noted that the proposed model of this research is intended to evaluate four suppliers. Figure 7 shows an overview of the cause and effect model.

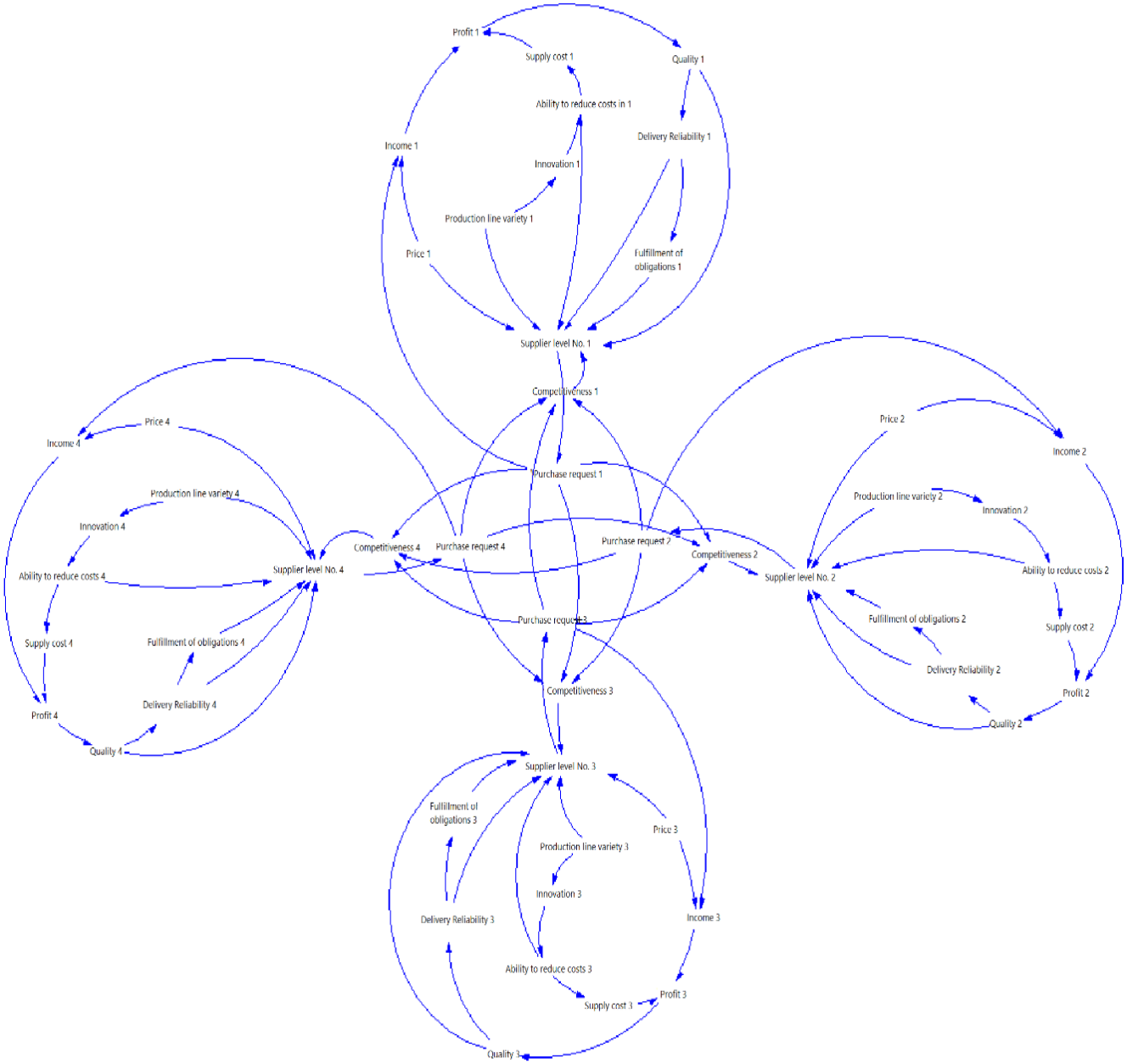


**Fig. 7**. Complete cause and effect diagram

### *3.4. Stock-Flow Diagram*

In the previous section, the cause-and-effect model shows the interdependencies and feedback processes in the supplier evaluation system. However, due to the limitations of this diagram, one of the most important of which is the inability to display the state variable structure and flow of systems, this section shows the relevant stock-flow diagram by introducing the existing variables. The stock-flow diagram consists of various elements, which are discussed below:

**Stock variable**: Stock variables (also known as stock level, inventory level, storage level, or reserve variables) are variables that determine the state of a system and create an information based on which decisions and actions are made. These variables only change over time, and their value at any given time depends on the value of this variable and other variables in previous times. These variables are displayed as rectangles. The value of each stock variable is equal to the accumulation of inflow minus outflow. In general, its mathematical concept is equal to:

$$\text{Stock (t)} = \int_0^t (\text{inflow(t)} - \text{outflow(t)}) + \text{Stock}(t_0) \quad (1)$$

**Flow variable:** Such variables describe the rate of accumulation within the system and reflect changes in stock variables over time. These variables are flows that enter or exit a stock variable. Therefore, the decision made in the form of flow variables affects stock variables over time. Input flows are represented by an arrow whose head is towards the stock variable and output flows are shown by an arrow whose head is outward to the stock variable.

$$\frac{\text{d(stock(t))}}{dt} = \text{inflow(t)} - \text{outflow(t)} \quad (2)$$

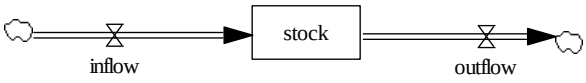


**Fig. 8.** Stock-Flow diagram

In this section, the relevant stock-flow charts are shown by introducing the available variables. Table 2 shows the variables and their types.

Table 2 shows that while the organization evaluates four suppliers, the model has four stock variables and four flow variables, and the other variables are auxiliary variables. Figure 9 shows the corresponding diagram.

**Table 2**. Stock-flow variables and their types

| Row | Variable | Type | Row | Variable | Type |
|---|---|---|---|---|---|
| 1 | The performance level of supplier 1 | Stock | 12 | Request to purchase from supplier 4 | Endogenous |
| 2 | The performance level of supplier 2 | Stock | 13 | Competitiveness of supplier 1 with others | Endogenous |
| 3 | The performance level of supplier 3 | Stock | 14 | Competitiveness of supplier 2 with others | Endogenous |
| 4 | The performance level of supplier 4 | Stock | 15 | Competitiveness of supplier 3 with others | Endogenous |
| 5 | Performance increase rate of supplier 1 | Flow | 16 | Competitiveness of supplier 4 with others | Endogenous |
| 6 | Performance increase rate of supplier 2 | Flow | 17 | Material price of supplier 1 | Exogenous |
| 7 | Performance increase rate of supplier 3 | Flow | 18 | Material price of supplier 2 | Exogenous |
| 8 | Performance increase rate of supplier 4 | Flow | 19 | Material price of supplier 3 | Exogenous |
| 9 | Request to purchase from supplier 1 | Endogenous | 20 | Material price of supplier 4 | Exogenous |
| 10 | Request to purchase from supplier 2 | Endogenous | 21 | The income of supplier 1 | Endogenous |
| 11 | Request to purchase from supplier 3 | Endogenous | 22 | The income of supplier 2 | Endogenous |
| 23 | The income of supplier 3 | Endogenous | 43 | The supplying cost for supplier 3 | Endogenous |
| 24 | The income of supplier 4 | Endogenous | 44 | The supplying cost for supplier 4 | Endogenous |
| 25 | The profit of supplier 1 | Endogenous | 45 | Ability to reduce costs by supplier 1 | Endogenous |
| 26 | The profit of supplier 2 | Endogenous | 46 | Ability to reduce costs by supplier 2 | Endogenous |
| 27 | The profit of supplier 3 | Endogenous | 47 | Ability to reduce costs by supplier 3 | Endogenous |
| 28 | The profit of supplier 4 | Endogenous | 48 | Ability to reduce costs by supplier 4 | Endogenous |
| 29 | The material quality of supplier 1 | Endogenous | 49 | Level of innovation in supplier 1 | Endogenous |
| 30 | The material quality of supplier 2 | Endogenous | 50 | Level of innovation in supplier 2 | Endogenous |
| 31 | The material quality of supplier 3 | Endogenous | 51 | Level of innovation in supplier 3 | Endogenous |
| 32 | The material quality of supplier 4 | Endogenous | 52 | Level of innovation in supplier 4 | Endogenous |

| | | | | | |
|---|---|---|---|---|---|
| 33 | Delivery reliability of supplier 1 | Endogenous | 53 | Business experience of supplier 1 | Exogenous |
| 34 | Delivery reliability of supplier 2 | Endogenous | 54 | Business experience of supplier 2 | Exogenous |
| 35 | Delivery reliability of supplier 3 | Endogenous | 55 | Business experience of supplier 3 | Exogenous |
| 36 | Delivery reliability of supplier 4 | Endogenous | 56 | Business experience of supplier 4 | Exogenous |
| 37 | The obligations fulfillment level by supplier 1 | Endogenous | 57 | The acceptance rate of risk in supplier 1 | Exogenous |
| 38 | The obligations fulfillment level by supplier 2 | Endogenous | 58 | The acceptance rate of risk in supplier 2 | Exogenous |
| 39 | The obligations fulfillment level by supplier 3 | Endogenous | 59 | The acceptance rate of risk in supplier 3 | Exogenous |
| 40 | The obligations fulfillment level by supplier 4 | Endogenous | 60 | The acceptance rate of risk in supplier 4 | Exogenous |
| 41 | The supplying cost for supplier 1 | Endogenous | 61 | Documentation of Supplier 1 | Exogenous |
| 42 | The supplying cost for supplier 2 | Endogenous | 62 | Documentation of Supplier 2 | Exogenous |
| 63 | Documentation of Supplier 3 | Exogenous | 68 | Production line flexibility in supplier 4 | Exogenous |
| 64 | Documentation of Supplier 4 | Exogenous | 69 | Business restrictions of supplier 1 | Exogenous |
| 65 | Production line flexibility in supplier 1 | Exogenous | 70 | Business restrictions of supplier 2 | Exogenous |
| 66 | Production line flexibility in supplier 2 | Exogenous | 71 | Business restrictions of supplier 3 | Exogenous |
| 67 | Production line flexibility in supplier 3 | Exogenous | 72 | Business restrictions of supplier 4 | Exogenous |

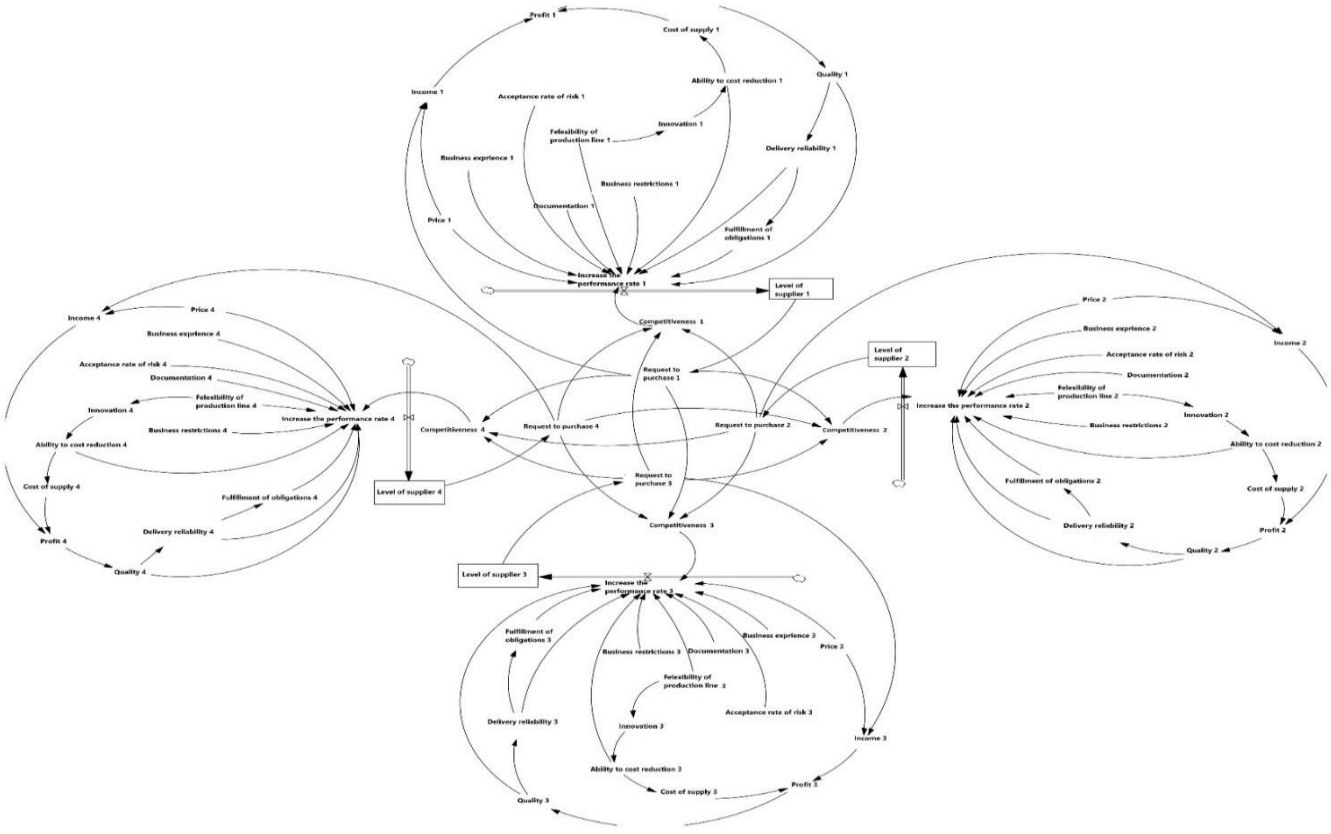


**Fig. 9**. Stock-Flow Diagram

## 4. Model Validation

In this study, after simulation, the validity of the proposed model has been examined by several tests, the results of which are given below.

### *4.1. Boundary Adequacy Test*

This test examines that important concepts related to the problem are considered within the model. In this study, the proposed model and its key variables have been identified and entered into the model based on literature review and expert opinions. In answer to the question of whether the behavior of the model shows a significant change after removing the assumptions of the boundary, the results of the proposed model were examined after removing parts of the model and changing the boundary of the model. Figure 10 shows the effect of deleting the "Purchase request" variable.

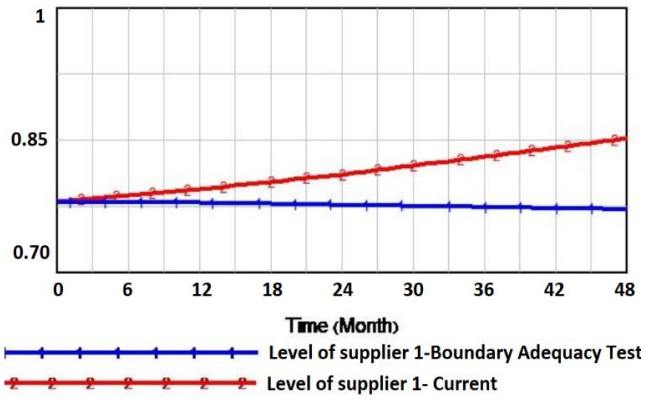


**Fig. 10.** Sensitivity analysis of the model to the purchase request variable in supplier 1

The red line refers to the case where there is a purchase request from supplier 1. In the blue line, this variable is assumed to be deleted. As can be seen in the blue chart, if there is no demand from the organization, as expected, the supplier's level will not grow much because its revenue and profit will decrease, and it will remain at the same level as before. From the addition of the amount produced to the amount of the initial inventory, it remains at the same level, and due to the lack of demand, there will be no delivery to other levels of the supply chain. This test can be performed for other suppliers and other variables.

### *4.2. Structure Verification Test*

The purpose of this test is to determine the compatibility of the model structure with the descriptive knowledge related to the system and to examine the rationality of the decision rules in shaping the behavior of the variables and the correct structure of the model equations. Since in this study, the model equations are written in Vensim software, the correctness of the model equation structure was confirmed by the software (Figure 11).

## 5. Analysis and Conclusion

Considering that the supplier selection is one of the important factors of profitability and survival of an organization, it is very important to choose a supplier that can sustain its status for a long time. on the other hand, how the suppliers behave and how they behave in front of other competitors, we have simulated and simulated a dynamic system model in the Vensim software to make a clear understanding of the behavior of suppliers and how each supplier behaves as it takes into account all the different aspects related to it, without affecting the other suppliers. The model structure is designed so that competition among the suppliers is considered so that if any of the suppliers face the risk they may start to change their performance and improve their performance. The systematic approach related to this study presents the evaluation results by considering the dynamic behavior of parameters and suppliers.

After examining the criteria for selecting and evaluating suppliers and modeling their quantitative and qualitative behaviors through system dynamics, the validity of the model was tested in different ways. The aim was to show from the output of the tests how much confidence the suppliers could have in predicting the future performance level of the suppliers. Suppliers were selected and evaluated based on the most important criteria extracted from the survey with a questionnaire and interviews with experts, which were often general criteria.

However, further efforts were made to take into account the competitive behaviors of suppliers and to use the system dynamics approach to simultaneously identify and prioritize each of them. Besides, proper decisions can be made if changes are made to each of the indicators. To this purpose, the scores of each indicator were recorded separately for each of the suppliers at the end of the two 12-month periods, and according to them and the feedback behaviors in the evaluation system, their performance was simulated for later periods.

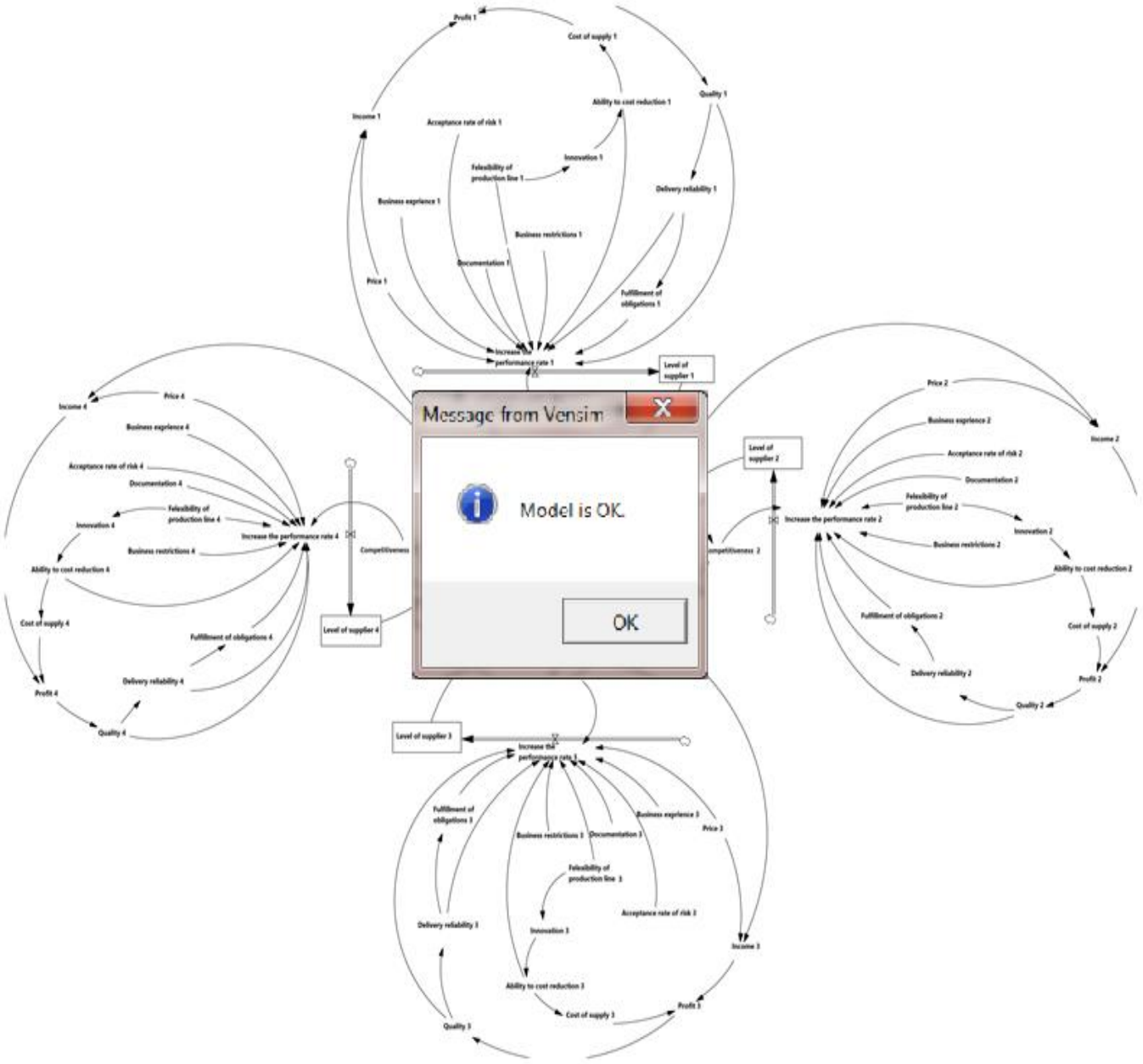


**Fig. 11**. Approval of model structure

Figure 12 shows the results of this simulation. It should be noted that the performance of each supplier has been evaluated on a scale of zero to one.

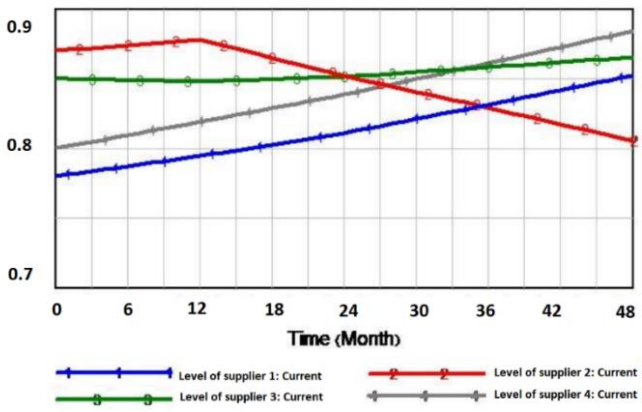


**Fig. 12**. Performance level of suppliers

As can be seen from Figure 12, the level of performance of supplier 2 is better than others. However, soon after that, the downtrend began, and it seems that the selection of this supplier is acceptable only in a short period. For supplier 4, although initially, its performance is not significant compared to supplier 2's performance, after a while it performs became better than other competitors in the medium term. To select a supplier in a long-term period, the supplier 3 first follows a growing performance to the extent that at the end of 48 months, its performance is better than other suppliers.

Obviously, if the organization's goals are set in such a way that it can select suppliers in combination, it is possible to propose a combination of suppliers 2, 3, and 4, respectively, 2-4-3. In this way, at the beginning of the work, priority should be given to the selection of supplier 2, and then the suppliers 4 and 3 should be used, respectively.

According to the findings and limitations of the present study, suggestions and orientations of research including: doing research for other sectors and organizations operating in those sectors to increase the capability of generalization and key results, in consideration of the political and economic factors governing the Razi institute, review further measures in future studies.

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# Effect of Slag Fineness and Curing Conditions on the Mechanical Properties of Alkali-Activated Blast Furnace Slag Mortars

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*Received: 07.04.2021 Accepted: 03.05.2021*

**Abstract-** The main objective of this experimental study was to investigate the effect of the slag fineness on the compressive and flexural strengths of ground granulated alkali-activated blast furnace slag mortars. Two types of alkali-activated mortar mixtures were produced using blast furnace slags having the Blaine fineness of 400 $m^2$/kg and 600 $m^2$/kg. Three curing methods; water curing, air curing and outdoor conditions, were applied to the samples. Compressive strengths and flexural strengths of the mixtures were determined at various ages and capillary water absorption tests were also performed. Test results confirm that increasing the fineness of slag had an important effect on the properties obtained. The curing method is also an important factor affecting the results.

**Keywords-** Blast furnace slag; alkali activation; fineness; curing conditions; mechanical strength; capillary water absorption.

## 1.Introduction

Alkali-activated materials have received much attention in the past decade due to their promising potential of replacing Portland cement. As is well known, the cement industry is one of the major producers of $CO_2$ emissions. Since the manufacturing process of Portland cement contributes considerably to $CO_2$ emissions, with the purpose of reducing the carbon footprint, many attempts have been made to find alternative binders to decrease the amount of cement used. Alkali-activated binders have been considered to be more environment-friendly due to the fact that the $CO_2$ emission is less compared to Portland cement[1, 2]. Aluminosilicates which are mostly reused industrial by-products and wastes are used as precursors in the production of alkali-activated binders. Many pozzolanic by-products are being used in cement as an alkali-activated binder, however, blast furnace slag is one of the most reused materials for this process resembling the Portland cement in chemical composition[3]. A growing body of literature has been investigated the mechanical and microstructural properties of alkali-activated cementitious composites blended by blast furnace slag[4-9]. The studies have shown that as the amount of blast furnace slag increases, an improvement in compressive strength occurs. On the other hand, it was reported that the dosages of the slag affect the workability and setting time of the cementitious composites[10, 11]. Also, the fineness and the curing conditions significantly affect the fresh and hardened properties as well[12]. In a study, it was noted that increasing the fineness of blast furnace slag resulted in the development of the strength of the binder by 50%[13]. Also, slags having two different blaine fineness were used for the alkali-activated binder and the development in strength due to the increase in blaine fineness was reported[14]. The use of blast furnace slag in cementitious composites is detailed by three grades in ASTM C 989 showing its potential as supplementary cementitious material[15]. The grinding process has an important effect on the particle size of the blast furnace slag. The relationship between the particle size and the specific surface area has significant implications in terms of the pozzolanic activity of the granulated blast furnace slag[16]. As stated, there has been an enhancement in strength due to the increase in fineness of the blast furnace slag. This observed increase in strength is explained by the increase in the specific surface area inducing an improvement in the reactivity of the blast furnace slag. Also, in recent studies, cementitious composites including granulated blast furnace slag activated with sodium carbonate and sodium silicate were compared and the changes in mechanical strength and setting time were discussed[17, 18]. Also, another study has used sodium carbonate and sodium silicate (waterglass) as activators to investigate the mechanical strength of alkali-activated blast furnace slag and waste of ceramic bricks and concluded that the axial compressive strength has improved for the

cementitious composites in which sodium silicate was used as the activator[19].

In this experimental study, blast furnace slag-based geopolymer mortars having different particle sizes were prepared using both sodium hydroxide (NaOH) and sodium silicate ($Na_2SiO_3$) as activators and the effect of blast furnace slag fineness on compressive and flexural strength of alkali-activated mortars was investigated under different curing conditions.

## 2. Experimental Study

### *2.1. Materials*

Blast furnace slags having two fineness values were used. Same ground blast furnace slag was used and was grounded in a laboratory ball mill. The initial Blaine fineness of the slag was 400 $m^2$/kg and was increased to 600 $m^2$/kg after the grinding. Chemical compositions of the slags are shown in Table 1 and some of their physical properties are given in Table 2.

**Table 1.** Chemical compositions of the blast furnace slags.

| Oxide Composition (%) | Slag BSA: 400 $m^2$/kg | Slag BSA: 600 $m^2$/kg |
|---|---|---|
| $SiO_2$ | 38.41 | 37.78 |
| $Al_2O_3$ | 10.22 | 10.07 |
| $Fe_2O_3$ | 1.53 | 1.58 |
| CaO | 37.71 | 37.56 |
| MgO | 7.88 | 8.08 |
| $SO_3$ | 0.63 | 0.65 |
| $Cl^-$ | 0.0381 | 0.256 |
| $Na_2O$ | 0.33 | 0.32 |
| $K_2O$ | 0.82 | 0.82 |
| Loss on ignition | 2.05 | 2.62 |

**Table 2.** Some physical properties of the blast furnace slag.

| Property | Slag BSA: 400 $m^2$/kg | Slag BSA: 600 $m^2$/kg |
|---|---|---|
| Density | 2.88 | 2.88 |
| Blaine surface area ($m^2$/kg) | 400 | 600 |
| Retained on 200 µm sieve (%) | 0.0 | 0.0 |
| Retained on 90 µm sieve (%) | 0.0 | 0.0 |
| Retained on 45 µm sieve (%) | 1.0 | 0.4 |

Figure 1 demonstrates that the average particle size decreases by grinding of the slag. The initial average particle was 45 µm, which was reduced to 8 µm after grinding.

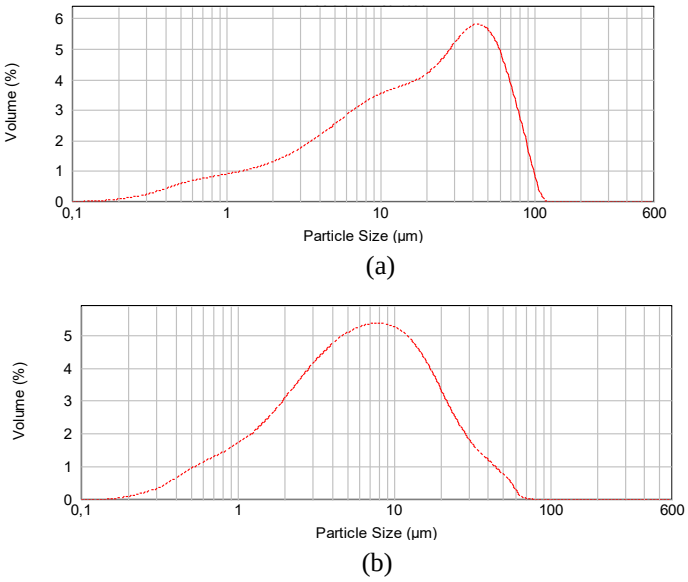


**Figure 1.** Particle size distributions of blast furnace slags (a) before grinding (b) after grinding.

In order to activate the ground granulated blast furnace slag, two different alkaline materials; sodium hydroxide and sodium silicate were utilized. Both of the activators were classified as the technical grade. Sodium hydroxide was in solid form and was dissolved in distilled water before using in the mixtures. Sodium silicate and sodium hydroxide solutions were used together for the activation of the blast furnace slags. The amounts of these activators in the solution by weight were 8% and 27%, respectively. The modulus of sodium silicate was 3. The density of the sodium hydroxide was ranging from 0.93 g/$cm^3$ whereas the density of sodium silicate solution was 1.33 g/$cm^3$. The same siliceous natural sand with a maximum particle size of 4 mm and a specific gravity of 2.563 g/$cm^3$ was used in the study.

### *2.2. Mixtures*

Two mortar mixtures were produced in the experimental work. The mixture proportions are given in Table 3. The mixtures were designated as BFS4 and BFS6 where BFS indicates blast furnace slag and the numbers following BFS show the fineness of the slag. For instance, BFS4 shows that the mixture was produced with slag having the Blaine fineness of 400 $m^2$/kg. Both of the mixtures were stirred in a laboratory mixer. 160 x 40 x 40 mm steel molds were used for casting of all specimen series and were unmolded after 24 hours.

### *2.3. Curing Conditions*

After demolding, three different curing conditions were applied;
i) Standard water curing at 20°C, or
ii) Laboratory air curing at 20±3°C and 60% relative humidity, or

iii) Outdoor conditions with an average temperature of 15±5ºC and varying humidity (such as rain).
These curing conditions were applied until testing.

**Table 3**. Mixture proportions.

| Mixture code | Blast furnace slag ($kg/m^3$) | Water ($kg/m^3$) | Na(OH) ($kg/m^3$) | $Na_2SiO_2$ ($kg/m^3$) | Sand ($kg/m^3$) | Unit weight ($kg/m^3$) |
|---|---|---|---|---|---|---|
| BFS4 | 466 | 233 | 32.6 | 79.2 | 1398 | 2209 |
| BFS6 | 468 | 208 | 32.8 | 79.6 | 1404 | 2192 |

*2.4. Testing*

Bending tests of the samples were made according to TS EN 196-1[20]. After this bending test, the compressive strength tests were conducted on the prism halves having a 40 x 40 mm cross-section. The compressive strengths of the specimens were also obtained with respect to TS EN 196-1. The mechanical properties of the specimens were tested at the ages of 3, 7, 28 and 56 days. To determine the permeability properties, capillary water absorption tests were made on the mixtures at the age of 56 days according to the requirements of TS EN 480-5 [21].

**3. Results and Discussion**

*3.1. Flexural Strengths*

The flexural strengths of the mixtures are given in Table 4. In this table, the letters O, L and W represent the curing conditions where O denotes the outdoor curing, L indicates laboratory air curing and W stands for water curing.

Figures 2 and 3 illustrate the flexural strengths of the mixtures produced with slag of 400 and 600 $m^2/kg$ fineness, respectively. As presented in these figures, water curing resulted in higher strengths. The flexural strength of the water cured samples were approximately 65 to 80% higher than the outdoor conditions. These results confirm that water is essential for the continuation of the hydration reactions. The 28-day and 56-day strengths obtained for the outdoor exposed specimens containing 600 $m^2/kg$ slag (BFS 6O), were lower than 7-day strengths. This may be due to the fluctuations in the humidity of the outdoor conditions. Reductions in humidity might have caused possible damages, such as micro-cracks at aggregate–paste interfaces, which may reduce the strength.

**Table 4.** Flexural strengths of the mixtures.

| Testing Age (Days) | Flexural strength (MPa) | | | | | |
|---|---|---|---|---|---|---|
| | BFS 4O | BFS 4L | BFS 4W | BFS 6O | BFS 6L | BFS 6W |
| 3 | 0.8 | 1.0 | 2.8 | 4.6 | 4.8 | 5.7 |
| 7 | 2.8 | 2.1 | 4.3 | 4.8 | 5.7 | 5.8 |
| 28 | 3.2 | 3.0 | 5.8 | 4.1 | 5.5 | 6.8 |
| 56 | 3.3 | 4.1 | 6.5 | 4.6 | 5.9 | 7.0 |

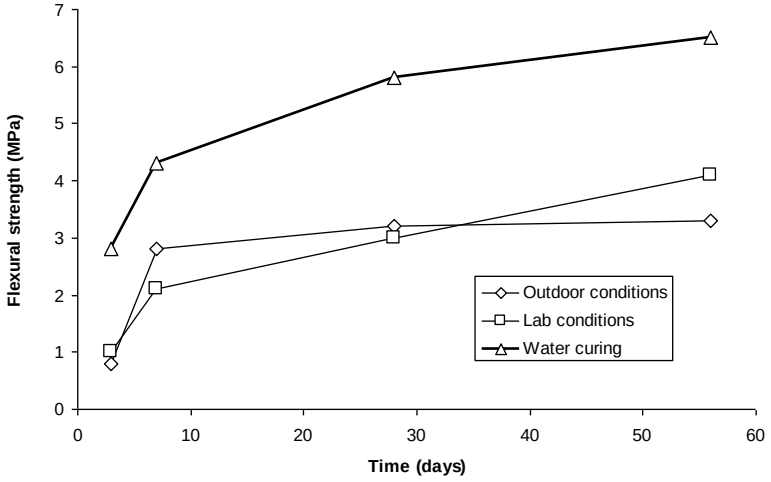


**Figure 2.** Flexural strengths of the mixtures produced with slag of 400 $m^2/kg$ fineness.

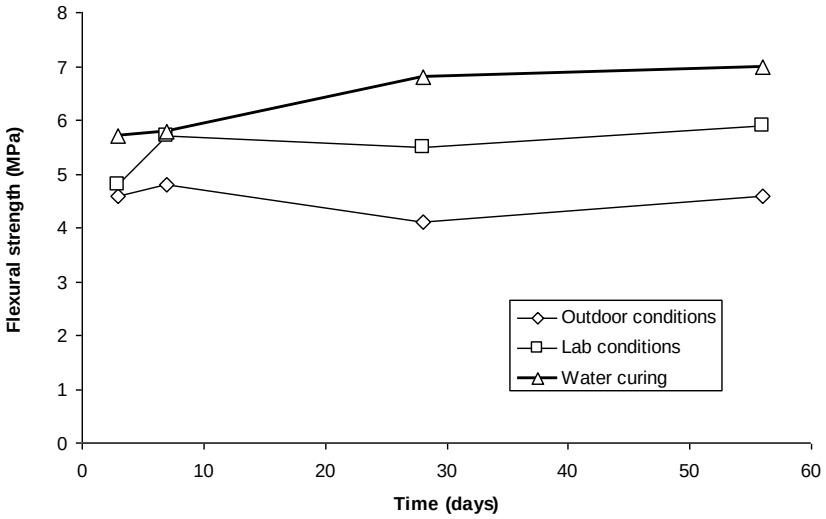


**Figure 3.** Flexural strengths of the mixtures produced with slag of 600 $m^2$/kg fineness.

When the effect of slag fineness is compared, it can be seen that the mixtures containing finer slag had higher strength values.

*3.2. Compressive Strengths*

Compressive strengths of the mixtures are shown in Table 5, and also in Figures 4 and 5. Similar to the flexural test results, the water-cured specimens achieved higher compressive strengths, as expected. Depending on these findings, it may be deduced that the effect of curing conditions for alkali-activated mixtures is similar to those for normal concretes.

Increasing the fineness of slag from 400 $m^2$/kg to 600 $m^2$/kg resulted in higher compressive strength. For example, after 28 days of water curing; the compressive strength of the mixture produced with 400 $m^2$/kg was 38 MPa, but that with 600 $m^2$/kg was 60.3 MPa, which corresponds to a strength increase of approximately 60%. This strength increase was more

**Table 5.** Compressive strengths of the mixtures.

| Testing Age (Days) | Compressive strength (MPa) | | | | | |
|---|---|---|---|---|---|---|
| | BFS 4O | BFS 4L | BFS 4W | BFS 6O | BFS 6L | BFS 6W |
| 3 | 4.5 | 6.9 | 12.2 | 25.1 | 25.9 | 27.5 |
| 7 | 16.1 | 14.8 | 21.1 | 33.7 | 43.1 | 47.7 |
| 28 | 18.8 | 26.6 | 38.0 | 38.7 | 54.6 | 60.3 |
| 56 | 46.9 | 50.5 | 58.5 | 40.5 | 58.7 | 63.6 |

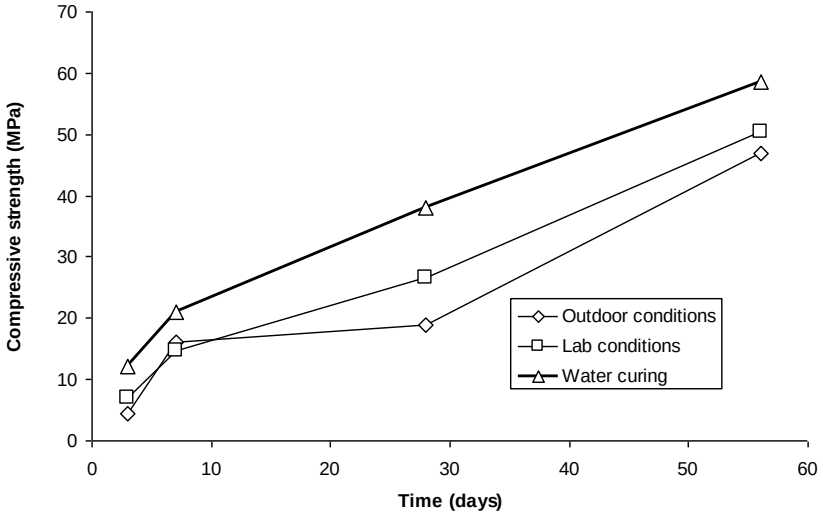


**Figure 4.** Compressive strengths of the mixtures produced with slag of 600 $m^2$/kg fineness.

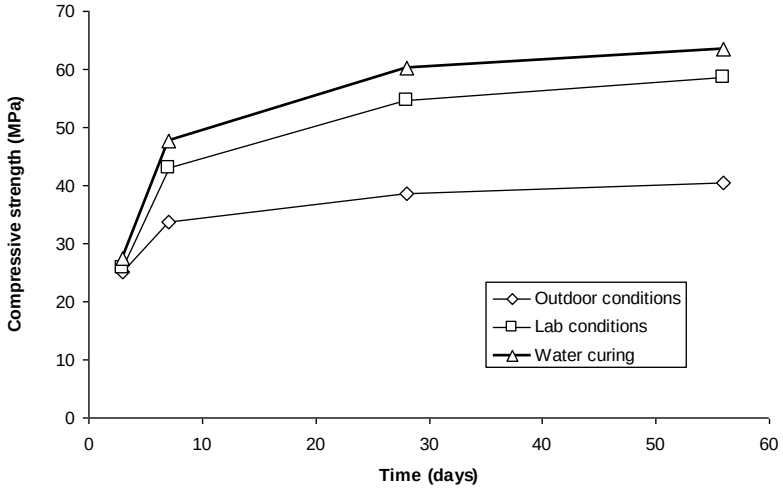


**Figure 5.** Compressive strengths of the mixtures produced with slag of 600 $m^2$/kg fineness.

significant for early ages. Similar strength increases were obtained also for the other curing methods.

### *3.3. Capillary Water Absorption*

Table 6 displays the results of the capillary water absorption test carried out with respect to TS EN 480-5. These tests were performed only at the age of 56 days. As seen in Figure 6, the fineness of slag had a significant effect on the capillary water absorption, especially for laboratory air curing and water curing. The reduction in capillarity was more than 60% for these two curing methods.

**Table 6.** Capillary water absorption of the mixtures.

| Fineness of slag ($m^2$/kg) | Capillary coefficient ($cm^2$/s) | | |
|---|---|---|---|
| | Outdoor conditions | Laboratory air curing | Water curing |
| 400 | 8.6 | 7.4 | 5.8 |

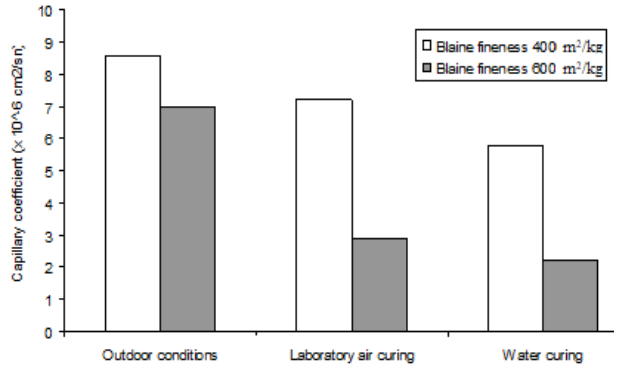


**Figure 6.** Capillary water absorption of the mixtures.

## 4. Conclusion

This experimental study has investigated the effect of slag fineness and type of curing on the mechanical properties of alkali-activated blast furnace slag mortar. Two different blaine fineness of 400 $m^2$/kg and 600 $m^2$/kg for the blast furnace slag were used and three kinds of curing methods, namely, water curing, air curing and outdoor conditions, were applied to the mortar samples. They were alkali-activated by both sodium hydroxide (NaOH) and sodium silicate ($Na_2SiO_3$). In conclusion, the compressive strength of the alkali-activated mortar increased significantly as the fineness of the blast furnace slag was increased. Also, higher flexural strengths were obtained by using a finely ground slag. It is observed that the fineness of slag also affected the capillary water absorption of the mixtures. The reduction in capillarity was more than 60% for laboratory air curing and water curing. On the other hand, according to all the test results obtained, the water-cured samples achieved the best results.

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# COVID-19 Quarantine Monitoring Based on Geofencing Technique

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*Received: 16.06.2021 Accepted: 18.06.2021*

**Abstract-** Smartphone and satellite network coverage contributes to a number of useful applications that increase the comfort of everyday people's lives. Using the Global Positioning System (GPS) provided by the satellite, people can be tracked in real time at a specific location. When it comes to infectious diseases such as COVID-19, the most important measure to reduce its spread is to contain it. Quarantine is usually a solution and any tracking system can be employed to specify the location of the infected people. However, as quarantined areas are scattered around the world, it is difficult to accurately trace the boundaries within accommodation. A geo-fenced GPS system, which has adopted an efficient border protection system, is proposed for quarantine and monitoring purposes of COVID-19 carriers. The system is introduced as an application to implement a home/local quarantine policy using bracelets that fit the boundaries of smartphones. From the experimental results obtained, it is observed that the proposed system achieves an effective and high accuracy performance in various location conditions.

**Keywords-** Quarantine; tracking system; GPS; GSM.

## 1. Introduction

The fact that Coronavirus Disease 2019 (COVID-19) is highly contagious has been an epidemic that has had a profound impact on people's lives and the economies of countries [1]. Therefore, prevention of infection by COVID-19 is the first step in effectively curbing its spread. People who have traveled from risky areas and had physical contact with infected cases are expected to be isolated and placed in quarantine areas for a period of 10-14 days. In many countries, mandatory quarantine orders are issued for those coming from abroad, whether at home or in care centers. Any breach of home quarantine (i.e. during the quarantine period when the infected person leaves the home) can pose a great risk and expense to public health.

Various technologies have been developed to locate any object. There are differences between these technologies, including cost, precision, functionality, scope, and coverage required to operate them, but choosing the right technique depends on the application or task required. Tracking infected individuals effectively and continuously is a challenge. One of the successful solutions has been to provide periodic satellite remote control reports on the location of infected people. Such reports can be provided daily and/or instantly by sending them to remote control devices based on satellite systems such as the Global Positioning System (GPS) [2-3]. Additionally, with the proliferation of Internet of Things (IoT) technology, analysts and programmers are using smartphones to perform transparent, automatic, and digital geographic isolation for isolated people over time. A typical technique is to

approximate using a global tracking system and then check if the infected person is within the limited allowable area. While this approach is accurate, it requires great effort to pre-calibrate inside and outside the quarantine zone. This is expensive and inflexible for more spread quarantine sites [4]. GPS technology can enable three-dimensional location information. Information on latitude, longitude and altitude can be provided using four GPS satellite signals. Global Mobile Communications System (GSM) modules can be used to find the exact location of coordinates from GPS satellites [5]. Often, a tracking device is operated to detect the movement of people or objects. Relevant position information must be combined in a timely manner so that the movement can be displayed on the tracking system. There are multiple tracking systems, some based on the latency after the target is reached, while others are near real-time and real-time systems [6]. The Real-Time Online (RTO) system collects the real-time position of the satellite and continuously returns the data to the server. The general online RTO system depends on GPS / GPRS / 2G for data relayed to the server [7]. In [8], a tracking system for the COVID-19 infected peoples that reside in quarantine areas by using geo-fencing technology, is designed and implemented. The restriction of the areas and the prevention of unknown people from entering these areas are done by the monitoring stations. The approach used to detect vehicle deviations beyond the prescribed safety zone in [9] is based on GPS. In short, vehicles are marked using a digital stamp by applying a tracking system based on geo-fence technique. In [10], a transition from a mobile-based to an infrastructure-based geofencing system is made by utilizing mobile clients that adjust their location update strategies according to the recommendations of the infrastructure and the different activities of the mobile client user. The system implemented in [11] is a new application framework introducing the geo-notification based services with the sentiment analysis. Combining GPS and GPRS in [12], the real-time tracking system analyzes the data received from the GPS receiver, providing the ability to track the current location or location of the vehicle at any specific time and date. In addition, information on vehicle status such as speed, mileage and driver performance is also provided. The vehicle tracking system of the research in [13] uses the Google maps service to track the vehicle, which has an account with posts of Google maps displaying vehicle location in real-time mode. A hardware module is built into the vehicle that uses GPS to detect the location and GSM to update the location in the vehicle account in the social network. The system in [14] is designed to prevent theft and make vehicle more secure by the use of GPS, GSM technology and a web application. Geofencing on the real-time GPS tracking system realized in [15] consists of two parts: the first part is used to receive GPS location data using the Sim908 device and send the data to a server using GSM and GPRS technologies, while the second part serves to display GPS data via web or Android application.

In this paper, a geofenced GPS system, adopting an efficient border protection system, is proposed for quarantine and monitoring purposes. It can be useful in monitoring infected individuals in quarantine, tracking vehicles, ships, and planes within geographical boundaries, etc. The microcontroller-based system includes GPS and GSM modules and is designed as a bracelet. The performance of the system is successfully tested under various location conditions.

## 2. Theoretical Background

### *2.1 Global Position System (GPS)*

GPS is a satellite based navigation system. The GPS contains three significant segments. The space segment is the shape of satellites that rotate around the Earth in multiple space orbits, piling up to six or more space orbits. The control segment is the ground equipment that performs the task of controlling the space segment, telemetry, satellite tracking and maintaining the satellite orbital configuration. The user segment is created from satellite receivers and is used to receive signals and identify sites based on received signals [16]. The GPS satellite sends a one-way signal to the GPS receiver on the ground. The satellite determines the location of the receiver and the time at which the signal is sent, as the timing information plays a major role in determining the location of the user. Therefore, the GPS contains an atomic clock to provide a time reference accurately [17]. The distance $d$ between a particular GPS satellite and the receiver can be found from the travel time $t_t$ of a signal from the satellite to the receiver as follows,

$$d = t_t \mathrm{c} = (\mathrm{t}_{sr} - t_{st})c \quad (1)$$

where $t_{sr}$, $t_{st}$ and $c$ are signal reception time, signal transmission time, and speed of light, respectively.

The actual position of the GPS receiver is obtained based on the GPS signal transit time from three nearby satellites and their precise trilateration (triangulation) of space coordinates. However, four satellites are required rather than three, in order to determine one's location in 3D space [18].

### *2.2 Geofencing*

The geofencing technique consists of a mixture of two operations, which are the frequent tracking of the location of a mobile device and the description of a geographical of interest region [2]. Geofencing collects information about the user's actual location, taking into account whether the user is close to places that might be relevant. To mark an actual location, it must assign its latitude and longitude. Latitude, longitude, and radius are determined by a geofence that creates a ring area or

fence around the entire monitoring site. This includes constantly checking and aligning mobile device location with a set of practical boundaries, i.e. geofences [19-20].

## 3. System Overview

In this section, the devices, libraries and algorithms used in the establishment of the system are introduced in general along with their working principles.

### *3.1 System Implementation*

The developed tracking system consists of a GPS L86 module, SIM800c GSM module, and microcontroller within the Arduino UNO board, which is utilized as the processing unit for the tracking system. The GPS receiver determines the location of the person i.e. the patient. Afterward, the obtained location data is sent to the server (adfruit.io) via GSM. Fig. 1 shows the circuit diagram of the tracking system.

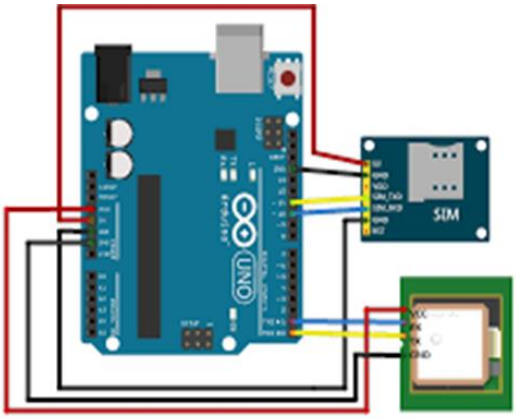


**Figure** 1: Interfacing GSM and GPS Module Using Arduino

COVID-19 infected individuals are tracked with a special application implemented using the MIT App Inventor platform. The application is compatible with smartphones running Android operating system. People who carry the recommended tracking system (in the form of a bracelet) can be tracked using this application. Therefore, a geofence technology is implemented to only allow the infected person to move within the geofence. Moreover, with the developed application, the dimensions of the geofence can be completely controlled, in other words, it can be enlarged or reduced.

### *3.2 System's Working Principle*

To obtain the latitude and longitude of a particular location, a practical test is first performed using the GPS module which is connected to the ATmega328P SMD microcontroller chip surface mounted in Arduino UNO. Two libraries named "SoftwareSerial.h" and "TinyGPS.h" are embedded with Arduino IDE for programming the code. The flow chart of the GPS working principle is shown in Fig. 2. The GPS receiver collects the longitude and latitude data, then the Arduino IDE serial monitor displays the received location data.

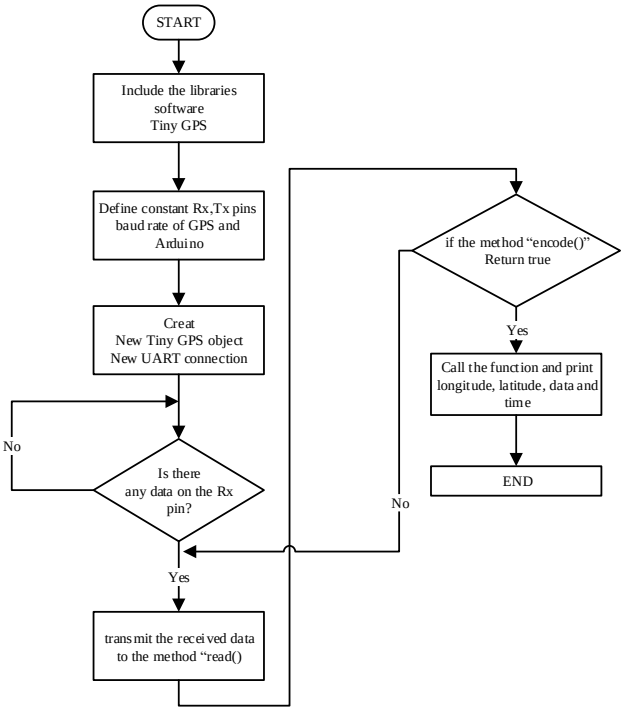


**Figure 2**: Working principle of the GPS module

In the GSM network, a SIM800 GSM module and the ATmega328P microcontroller chip are used to transmit data to the Adafruit server. In practice, the person holding the proposed tracking system (i.e. bracelet) does this. AT command mode is used for programming data transfer commands. The flow chart for the GSM operation is shown in Fig. 3.

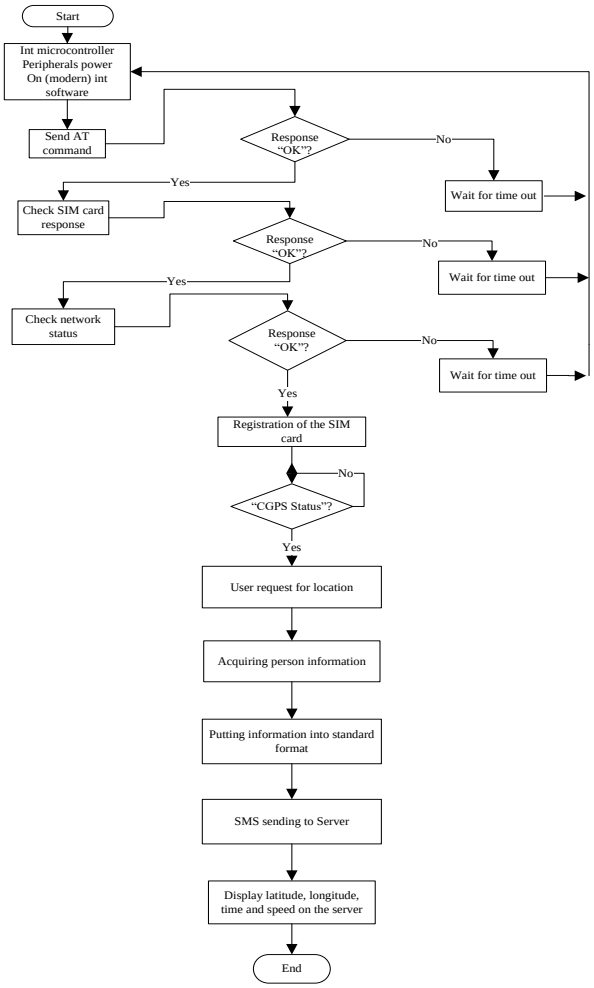


**Figure 3**: Working principle of GSM module

AT commands can be used to test the connection between the operation of the GSM module and the cell phone base station. For geolocation data (latitude, longitude, time and speed), the receiver receives the information of the GPS signal and then sends this information to the server. Fig. 4 shows the flowchart of sending and receiving data.

*3.3 The Server (Adafruit.Io)*

Adafruit.io cloud service is used to view the data in real time. The server port number 1883 is used when setting the hostname to asio.adafruit.com in the Arduino IDE. The code consists of Adafruit account username, regenerable special AIO key, feed setup and feed name, SSID, and internet port password. The feed name is the subject name that can be subscribed or published for internet connection through the server. To properly establish the relationship connecting the Arduino and the server, the code is compiled and sent to the control. It also shows the definition of the server name, server port, and key assigned to the server.

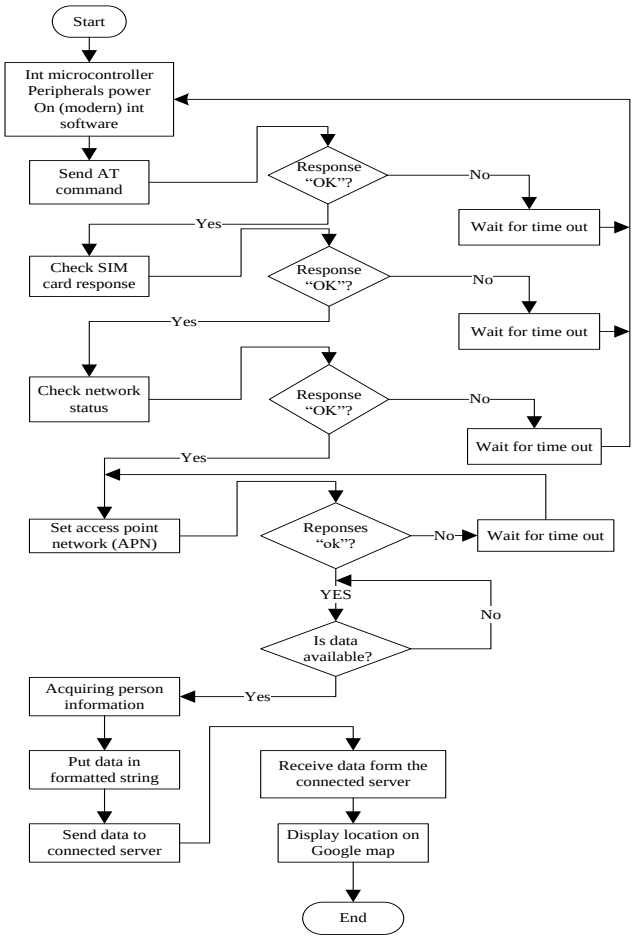


**Figure 4**: Flowchart of sending and receiving data

*3.4 Geofencing Application*

In this study, geofencing incorporates the actual position of the patient with the proximity of the patient to the quarantine site. The quarantine site is marked by specifying its latitude and longitude while the proximity to the defined site is determined by adding a radius. Thus, the applied geofencing is in a circular shape [9]. The geo-fencing here is applied via the MIT App Invertor for Android. The proposed system is designed and implemented to meet the need for a proper quarantine as well as the ability to locate, and adjust quarantine site boundaries with this Android app. It also gives a warning on the exit or entrance of the patient carrying the tracking device (in this case a bracelet), as shown in Fig. 5.


**Figure 5**: Applied circular geofencing

To summarize, with the geofencing based tracking system, first the location data (longitude and latitude) is received from the satellites by the GPS receiver and then transferred to the ATmega328P microcontroller for further processing, and then the obtained data is transmitted by the GSM module to the Adafruit server to be displayed in the mobile application.

## 4. System Implementation and Results

### *4.1 Tracking Device - Bracelet*

Fig. 6 shows the block diagram of the bracelet design used as the tracking device.

The circuit of the designed tracking system - the bracelet includes the microcontroller, GPS and GSM modules given in Fig. 1 altogether. The bracelet circuit contains GPS&GSM (SIM800C) modules, ATMEGA328P microcontroller, Common Mode Filter (ZJYS51R5), Switcher (LM2596), voltage regulator (SPX3819), a set of Headers, GPS and GSM antenna (IPEX3), a set of LEDs, and an IC Charge (MCP73831) unit. The double-sided Printed Circuit Board (PCB) of the bracelet is shown in Fig. 7.

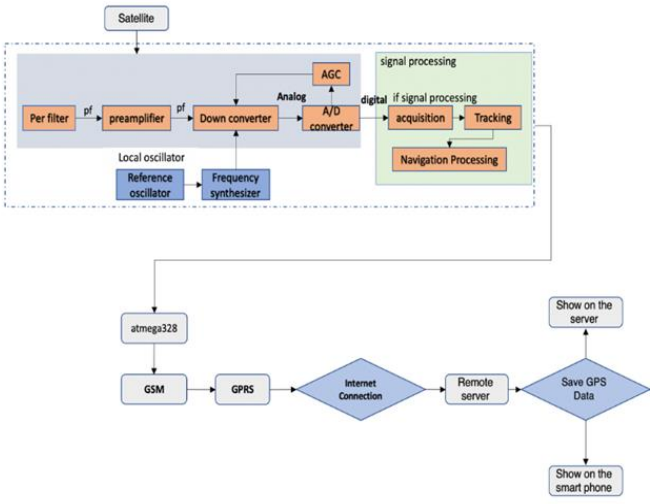


**Figure 6**: Block diagram of the tracking device - bracelet

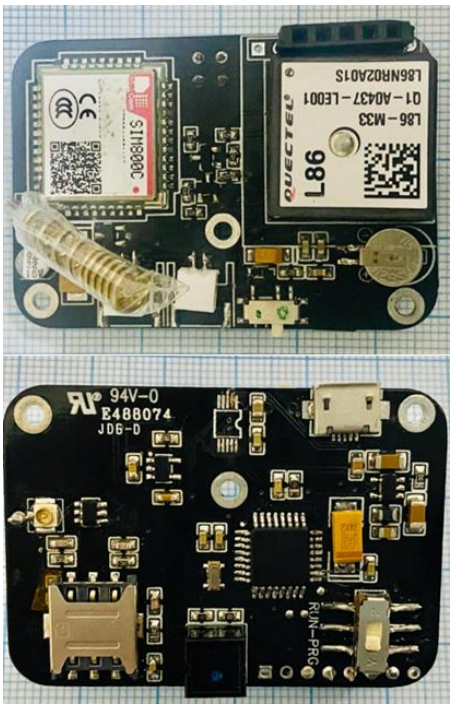


**Figure 7**: PCB of the implemented tracking device - bracelet

### *4.2 Web Server and Database*

The microcontroller is connected to the SIM800 module of the GSM shield, to act as an SMS transceiver. In general, the tracking device sends an SMS condition request constantly to the unit, at any time the central server wants to find the patient. The GPS inside the bracelet sends the received data continuously to the server via GSM. This data includes the coordinates (latitude and longitude), time, and speed. In a smartphone application, the server derives the coordinates from the data, which is received by SMS. The patient's location is displayed on the mobile phone map and archived in the database for potential future use. The web server is linked to the database, which contains information about the patient's location. A sample of experimental data of patient location information obtained from the database based on a test run is listed in Table 1.

Table 1. Real-time patient location information.

| TIME | DATA | LAT | LON | ALT |
|---|---|---|---|---|
| 16:27:22 | 30-12-2020 | 40.986855 | 28.708899 | 98 |
| 16:27:24 | 30-12-2020 | 40.986865 | 28.708908 | 98 |
| 16:27:26 | 30-12-2020 | 40.986878 | 28.708914 | 98 |
| 16:27:28 | 30-12-2020 | 40.986886 | 28.708921 | 98 |
| 16:27:30 | 30-12-2020 | 40.986894 | 28.708928 | 98 |
| 16:27:32 | 30-12-2020 | 40.986907 | 28.708933 | 98 |
| 16:27:34 | 30-12-2020 | 40.986915 | 28.708941 | 98 |

Experimental results show that the minimum time for updating location information is 2-4 seconds. This time can be configured according to the individual movement.

*4.3 Geofencing Performance Validation*

The application is run on Android phones and two types of commands are executed, 'fence' and 'patient'. The 'fence' command specifies the geo-fence, while the 'patient' command specifies the bracelet holder location. Apart from the geo-fence and the patient's location, the distance and speed of the patient to the geo-fence are also displayed on the screen. The tracking system automatically updates the patient's location every 3-5 seconds. To validate the performance of the geofencing based tracking system three different scenarios are examined.

In the first scenario shown in Fig. 8, the blue marker and red marker/circle represent the patient wearing the bracelet and the geographic boundary for quarantine, respectively. It can be observed that a green message indicates that the patient is within the geofencing boundaries, that is, within the quarantine area. In the second scenario shown in Fig. 9, when the patient crosses the geofence, the distance between the patient's location and the geofence is calculated. An alert is sent to the mobile phone and a red message indicates that the patient is outside the quarantine area. The alert works continuously until the distance between the patient and the geofence equals zero, meaning that the patient is within the quarantine zone when it stops.

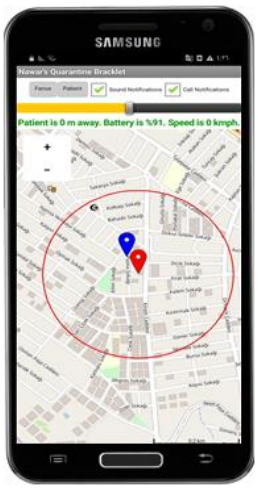


**Figure 8**: Patient located within the geofence


**Figure 9**: Patient located outside the geofence

The third scenario illustrates the ability to change the boundaries of the geofence. Thus, the diameter of the geofence can be adjusted according to the specified area for monitoring. The tracking device is programmed with maximum and minimum distances of 1 km and 200 m, respectively. Fig. 10 shows the patient's position within the increased boundaries of the geofence.


**Figure 10**: Enlargement of geographic boundary

The bracelet has a solid design, so it can be used in different climatic conditions and is connected to the mobile phone using the cloud. The complete tracking system (bracelet and mobile device) is shown in Fig. 11.

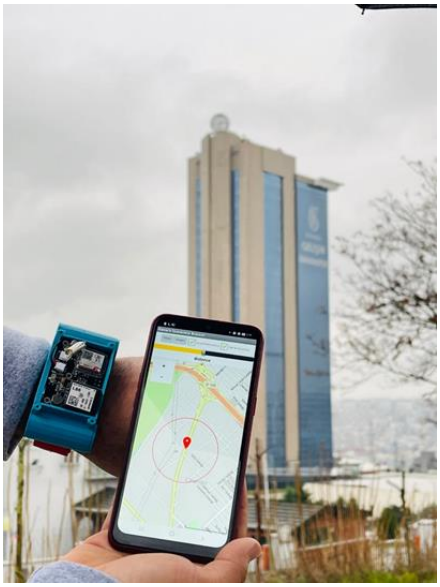

**Figure 11**: Complete system (bracelet and mobile device)

## 5. Conclusion

A real-time tracking system based on geofence technology has been demonstrated and developed. The tracking system has been proposed as an alternative to the recently required strict quarantine policy. It consists of a bracelet containing GPS&GSM modules and a microcontroller, and a mobile device. People infected with COVID-19 are tracked with a special application implemented using the MIT App Inventor platform. The application is compatible with smartphones running the Android operating system. For geolocation data (latitude, longitude, time and speed), the receiver receives the GPS signal information and then sends this information to the web server.

Geofencing technology provides accurate real-time information that enables the person responsible for monitoring to quickly track the person leaving the specified area. An alert is sent to the mobile phone when the patient crosses the boundaries of the geofence. The performance of the implemented tracking system has been verified by experiments under various conditions.

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INTERNATIONAL JOURNAL of ENGINEERING TECHNOLOGIES-IJET
Ediz, Vol.7, No.2, 2021

# Identification with Face Recognition Methods in Real Life Applications

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*Received: 30.10.2020 Accepted: 18.07.2021*

**Abstract-** The development of technologies such as employment tracking systems, personal security, and the use of robots has led a lot of studies on face recognition systems. In the most of studies considering face recognition, recognition accuracies are very high, since training and testing images are selected randomly from the same databases. However, in real life applications, these images are not randomly selected from the same database. Because, these systems are trained during installation of the recognition system or when a new person needs to be introduced to the system. On the other hand, images used for predictions are uploaded to the system at other times. In this study, it is aimed to show that the accuracy rates of real-life face recognition systems differ from the systems trained and tested with randomly selected images as usually done in literature. To observe this difference in the first step, training and test images are selected randomly. In the second step, training and test images are divided according to the recording dates as in real life. Accuracy rates are evaluated by using linear discriminant analysis, local binary patterns and principal component analysis methods. Although the accuracies are very high for the first step, it is seen that the accuracies fell dramatically in the second step for all methods. Afterwards a new method is searched also in this study to increase these low accuracy rates. It is shown that usage of eye area images instead of face images has higher accuracy rates in all above methods for real life applications.

***Keywords:*** Eye Area Recognition, Face Recognition, Image Processing, Linear Discriminant Analysis, Local Binary Patterns, Principal Component Analysis, OpenCV

## I. Introduction

Face recognition systems are generally considered in two groups as feature-based methods and holistic approach methods. In feature-based methods, the face to be recognized is compared with other faces in the database by using certain geometric features [1]. In holistic methods, machine learning and deep learning techniques are used. The system continues to learn with the fed digital images and uses the learned features while comparing the newly encountered images with those in the database. Although different methods have been developed in face recognition systems, it is still very hard to get 100% accurate results from these systems [2]. The current methods have some advantages and disadvantages. While training times of some holistic approach methods, such as deep learning, take more time, training times of feature-based methods are generally take short time. On the other hand, accurate prediction rates of holistic approach methods are higher than feature based methods.

In the studies considering face recognition, databases offering ready face images are frequently used. There are many databases created for using in face recognition research, such as Yale database, AR Face database, CAS-PEAL database, FERET database, XM2VTS database, PIE database, and KFDB [3].

Considering the existing literature on face recognition, in a study using a ready database with face images, OpenCV and Dlib libraries, which are popular in face recognition systems, are compared, and OpenCV's performance is found to be higher [4]. In another study, the faces in the MOBIO database obtained by using mobile devices are compared with the face recognition systems used in OpenCV and the best performances are obtained with LDA in high image sizes and with LBPH in low image sizes [5]. In their study, Abdülsamed and Olcay observed that, using the AT&T database in facial recognition, successful results were achieved. However while they used the actor images in the movies, an average success was achieved [6]. They attributed the high recognition rate in the ready database to the constant positioning and lighting environment. On the other hand, images captured from daily life obtains low rate recognition rates because of reasons like very different light levels, different perspectives and applying

different makeup to people at different times ([6], [7]). In Aksoy's study [8], front, side, upper and lower face images were taken from volunteer students and faculty members. The best results were obtained with PCA and SVD algorithm in the front and side face recognition system, and with the LBP algorithm in the upper and lower face recognition systems. Also, different algorithms were developed for face recognition systems in literature and the success of these algorithms in face recognition was evaluated by using known face databases such as Yale Database [9]. In recent researches, deep learning also are used to detect faces in face recognition systems [10].

It can be estimated that if training and testing images are obtained on different dates like in real life applications, the recognition systems' accuracy rates will be decreased. To investigate this estimation, this study is prepared. First of all, some recognizer methods are used to see the results. In the next section, selected face recognizer methods are investigated. Afterwards, in Section III, recognition systems' prediction rates are compared for randomly selected face images and different date recorded face images. In Section IV, a new method is applied to increase recognition accuracy rates.

## II. Selected Face Recognizer Methods

In this article, holistic approach face recognition methods based on statistical calculations are used. These are the methods in OpenCv library called as Eigenface, Fisherface and Local Binary Patterns Histograms (LBPH). Among these methods, Eigenface and Fisherface recognizers make a face prediction based on machine learning with a holistic approach, while LBPH recognizer makes face prediction using local differences.

In Eigenface recognizer and Fisherface recognizer methods, the dimension number of the gray scale image vector equal to the pixels' number is reduced to a reasonable level. Then image vectors with reduced dimensions are used in trainings and predictions. The Eigenface recognizer method uses the difference of faces to the average face image. Fisherface recognizer, on the other hand, uses the average face images on faces classified by labels instead of average image of all faces. Thus, Eigenface recognizer classifies images using the Principle Component Analysis (PCA) method [11] and Fisherface recognizer classifies images using Linear Discriminant Analysis (LDA) method [12] .While PCA tries to maximize the distance between all variables, LDA tries to maximize the distance between classes [13]. Although LDA performs better than PCA except for low test numbers, it has difficulty in processing high-dimensional image data ([14], [15]).

In both methods, covariance matrices are calculated and eigenvalues and eigenvectors of covariance matrices are found. The number of dimensions in an image that is equal to the number of pixels is reduced to used image numbers. By selecting eigenvectors with high eigenvalue, the number of data can be further reduced. Afterwards, weights of trained images on eigenvectors are calculated. When an unknown image comes, the distances of this image from each trained images are calculated and the image is predicted by a classification method such as the nearest neighbor.

As the third method, LBPH face recognizer technique uses local differences in the image. In this technique, image pixels are divided into squares in certain size. Perimeter square pixels get 1 or 0 depending on whether they are larger or smaller than the middle pixel value. Perimeter square values are written in binary value by starting from the upper left corner and progressing clockwise, and then the obtained value is converted to decimal value and assigned to the central square value. By creating a histogram with the obtained values, the histogram values of the images are compared [16]. Since the face recognition system based on the LBPH technique makes local comparisons, it is less affected by the light level differences on the face images than the Eigenface and Fisherface techniques.

## III. Comparing Prediction Rates of Randomly Selected Face Images with Different Date Recorded Face Images

In this study, images, captured at 0.2 second intervals from the videos, were used for face detection with haar cascade algorithms which are widely used in finding the facial region. These algorithms, which are presented by Viola and Jones (2001) and used in face detection, search whether the black and white areas in different combinations are present in the image [17]. The haar cascade classifiers make face detection faster than the previous face detection systems. In this study, different videos of 8 people were used to generate image data. In order to detect face images, face haar cascade algorithm is used. Some face images of the same child (Person ID 2) attained by using face haar cascade algorithm can be seen in Figure1.


**Figure 1:** Some face images of the same child (Person ID 2) captured at different dates from the prepared database.

Videos recorded at different times for each person were used in the study. In the first step, images obtained from different date records were mixed randomly and some of these images were used for education and some of them were used for testing. The results of this step can be seen in Figure 2. The accuracy rates of randomly selected images for PCA, LDA and LBPH are 78.4; 83.2; 90.3 sequentially. LBPH attained the highest accuracy. The worst results are taken from the child whose PersonID is equal to 2.

| PersonID | PCA | | | LDA | | | LBPH | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | True | False | Not Found | True | False | Not Found | True | False | Not Found | |
| 1 | 59 | | 10 | 62 | 7 | | 61 | | 8 | 69 |
| 2 | 30 | | 46 | 42 | 34 | | 55 | | 21 | 76 |
| 3 | 46 | | 13 | 39 | 20 | | 46 | 4 | 9 | 59 |
| 4 | 56 | | | 53 | 3 | | 56 | | | 56 |
| 5 | 34 | | 10 | 35 | 9 | | 44 | | | 44 |
| 6 | 55 | | | 55 | | | 55 | | | 55 |
| 7 | 38 | | 16 | 49 | 5 | | 51 | | 3 | 54 |
| 8 | 45 | | 5 | 50 | | | 50 | | | 50 |
| Total | 363 | 0 | 100 | 385 | 78 | | 418 | 4 | 41 | 463 |
| | Accuracy (%): 78.4<br>Error (%): 0<br>Not Found (%):21.6 | | | Accuracy (%): 83.2<br>Error (%): 16.8<br>Not Found (%):0 | | | Accuracy (%): 90.3<br>Error (%): 0.9<br>Not Found (%):8.9 | | | |

**Figure 2:** Prediction results of randomly mixed face images used in both train and test

In the second step, some of the videos taken on different dates were used for training and some for testing. The number of training images (383) and the number of test images (463) for both stages (first and second stages) were prepared to be the same. After these preparations, the accuracy rates of face recognition processes based on PCA, LDA and LBPH methods were calculated for the images at both stages. In this step, the accuracy rates of images for PCA, LDA and LBPH are 9.1; 44.7; 43.2 sequentially and LDA attained the highest accuracy as seen in Figure 3.

| PersonID | PCA | | | LDA | | | LBPH | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | True | False | Not Found | True | False | Not Found | True | False | Not Found | |
| 1 | 13 | | 56 | 41 | 28 | | 41 | | 28 | 69 |
| 2 | | | 76 | 10 | 66 | | | 3 | 73 | 76 |
| 3 | | 2 | 57 | 11 | 48 | | 12 | 33 | 14 | 59 |
| 4 | | | 56 | 41 | 15 | | 48 | 7 | 1 | 56 |
| 5 | | | 44 | | 44 | | | 18 | 26 | 44 |
| 6 | | | 55 | | 55 | | | | 55 | 55 |
| 7 | 11 | | 43 | 54 | | | 49 | | 5 | 54 |
| 8 | 18 | | 32 | 50 | | | 50 | | | 50 |
| Total | 42 | 2 | 419 | 207 | 256 | 0 | 200 | 61 | 202 | 463 |
| | Accuracy (%): 9.1<br>Error (%): 0.4<br>Not Found (%):90.5 | | | Accuracy (%):44.7<br>Error (%): 55.3<br>Not Found (%):0 | | | Accuracy (%): 43.2<br>Error (%):13.2<br>Not Found (%):43.6 | | | |

**Figure 3:** Prediction results of test face images which have different dates from training images' dates

When images of people taken at different times; perspective, hairstyle, facial expressions, aging, light decrease the effectiveness of recognition systems. So, because of the factors related to time and situation, the effectiveness of recognition systems is greatly reduced as seen in Figure 4. Face recognition systems used in real life will face such problems. In order to reduce these problems as much as possible, a method is developed in the next section and compared with the classic face recognition methods.

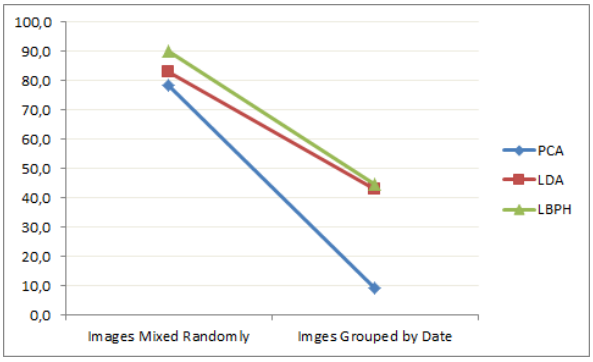



**Figure 4:** Accuracy rates of images mixed randomly and images grouped by date

## IV. A New Method For Real Life Applications

When trying to detect a face image using trained images taken at different dates, the accuracy rates decreased. For this reason, eye areas will be used to detect Person ID instead of faces to test the accuracy rates with the same methods.

EmguCV library derived from OpenCV is used in this study because the methods are written in Visual Studio Environment with C#. The steps of the algorithm to find and store the eye area images can be seen Figure 5. In these steps, first of all, face and facial images are obtained using haar cascade classifiers from training videos. Then, two eyes belonging to the same face are found. The eye area images are scaled depending on the two eye distances and rotations are made so that the lines passing through the two eye centers are on the horizontal axis. The images are converted to grayscale and a specified width and height in pixels, then they are archived in training group or test group.

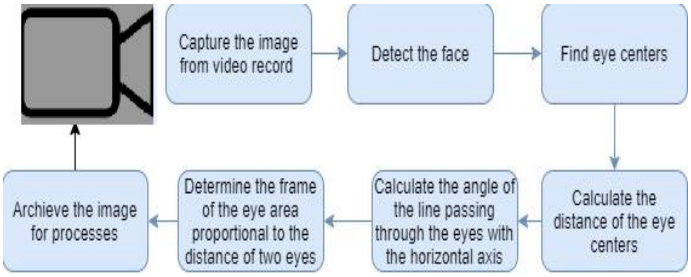



**Figure 5:** Algorithm steps to store the detected eye area images

Eye area images, stored in training group, are trained by using Eigenface recognizer, Fisherface recognizer and LBPH face recognizer methods. Threshold values of Eigenface recognizer, Fisherface recognizer and LBPH face recognizer methods used in the application are 4000, 2500 and 80, respectively. Then, eye area images in test group are predicted using the above methods. After predictions, the results are evaluated.

Eye haar cascade classifier and rule-based algorithms to detect the eyes belonging to the same face [18] are used in this step. However, eyes could not be detected in some of the faces in the database, since the desired conditions were not met. In approximately half of the detected face images, two eyes were found meeting the desired conditions [18]. On the faces detected eyes, the angle of the line passing through the center of the eyes was determined and the eye area image was rotated accordingly. In addition, by taking reference from two eye distances on the face images, the boundaries of the eye area images were determined and the image obtained was scaled to a certain size as seen in Figure 6.

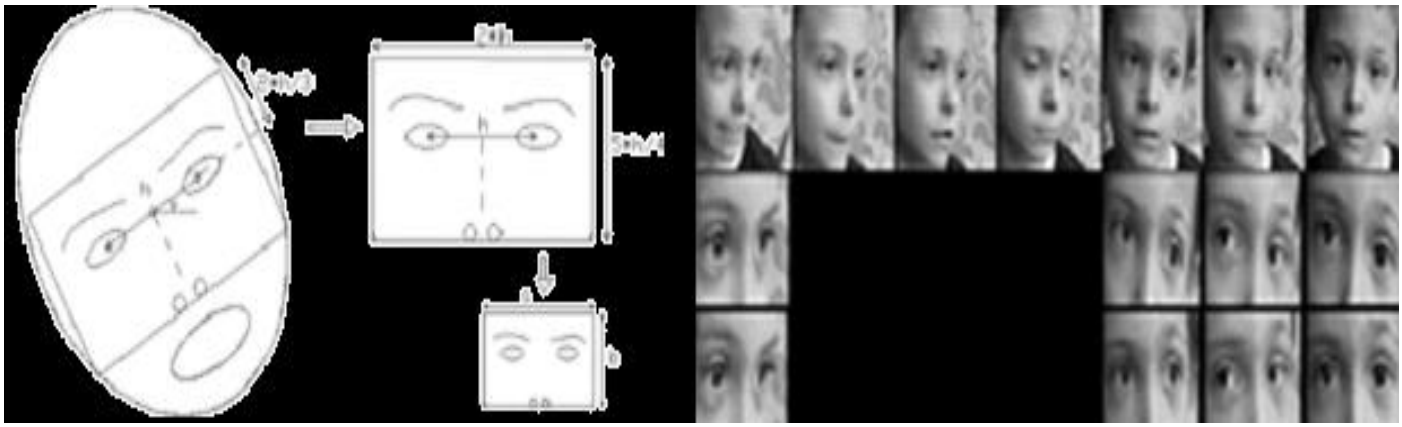


**Figure 6:** Trimming, rotating and resizing of eye area image

In this study, training and test videos were recorded at different times. The eye area images (174) used in training were obtained from the archived training faces (383) and the eye regions images (208) used in the test were obtained from the archived test faces (463). Pixel sizes of all images were equalized before archiving and each image was recorded under its own group and ID number. In this step, the accuracy rates of eye area images for PCA, LDA and LBPH are 21.6; 61.5; 52.4 sequentially and LDA attained the highest accuracy as seen in Figure 7.

| PersonID | PCA | | | LDA | | | LBPH | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | True | False | Not Found | True | False | Not Found | True | False | Not Found | |
| 1 | 5 | | 3 | 5 | 3 | | 5 | 3 | | 8 |
| 2 | | 13 | 22 | | 35 | | | 35 | | 35 |
| 3 | | 29 | | 20 | 9 | | 19 | 10 | | 29 |
| 4 | | 7 | 19 | 26 | | | 26 | | | 26 |
| 5 | | 9 | | | 9 | | 9 | | | 9 |
| 6 | 39 | 12 | | 27 | 24 | | | 51 | | 51 |
| 7 | 24 | | | 24 | | | 24 | | 0 | 24 |
| 8 | 25 | | 1 | 26 | | | 26 | | | 26 |
| Total | 93 | 70 | 45 | 128 | 80 | 0 | 109 | 99 | 0 | 208 |
| | Accuracy (%):44.7<br>Error (%): 33.7<br>Not Found (%):21.6 | | | Accuracy (%):61.5<br>Error (%): 38.5<br>Not Found (%):0 | | | Accuracy (%): 52.4<br>Error (%):47.6<br>Not Found (%):0 | | | |

**Figure 7:** Prediction results by using eye area test images which have different dates from training images' dates

In all three methods, the accuracy rates of eye area images' predictions are higher than face images' predictions for different date recorded images as seen in Figure 8. The highest accuracy rates in both face and eye area estimates are obtained with the Fisherface recognizer (LDA). However, the highest value of these accuracy rates are found to be 61.5% and still not very high.

The confusion matrices of the predictions are evaluated using the archived training and test images and the following findings areobtained. Predictions for Person ID2 are wrong totally. It is seen that the images obtained from the video used for training (14 images) and the images used for testing (35 images) have different perspectives from each other (Some images of Person ID 2 can be seen in Figure 2).

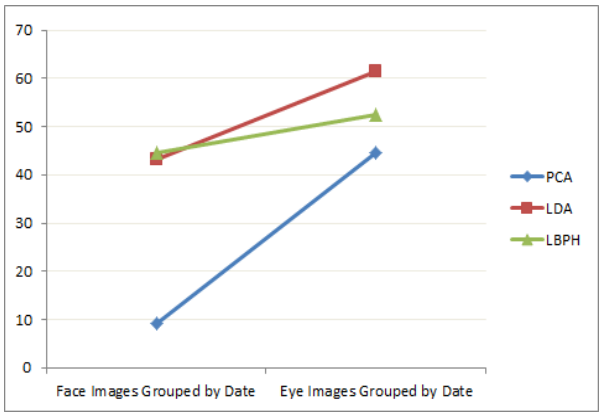
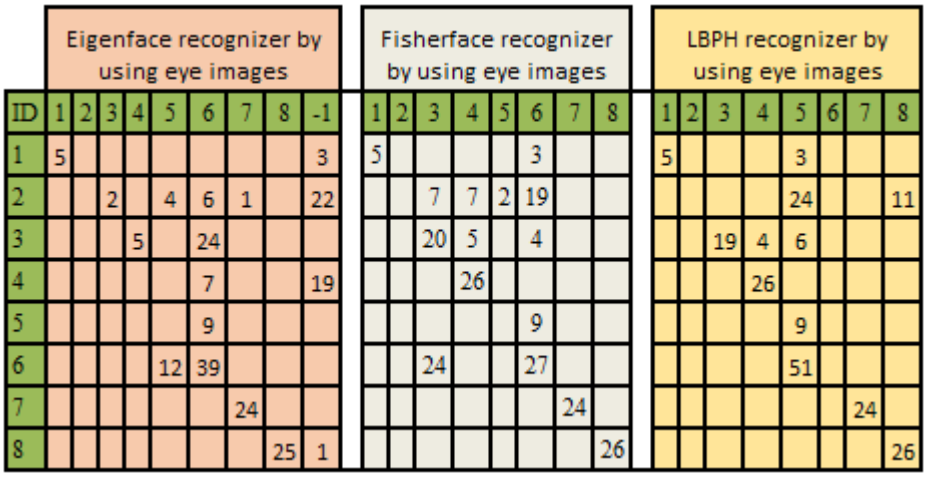



**Figure 8.** Accuracy rates for face and eye images when training and testing groups are separated

For Person ID 5, all of the eye area predictions, by using Eigenface and Fisherface recognizers, are false whereas all of the eye area predictions with LBPH recognizer are true, as seen in confusion matrices (Figure 9). It is noticed that average pixel values are different between training and testing images. That is, the average of pixel value of grayscale images in educational group is 112, whereas the average of pixel for grayscale images in test group is 60. So, it can be concluded that while PCA and LDA methods are affected by light differences, LBPH method is not affected. When histogram equalizations are performed on the same images to decrease light effect, the accuracy of the eye area images' predictions of Person ID 5 is increased. However, in this case, while total accuracy rates of Eigenface recognizer and LBPH face recognizer are increased, the Fisherface recognizer's total accuracy is rate decreased. .



| | Eigenface recognizer by using eye images | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ID | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | -1 |
| 1 | 5 | | | | | | | | 3 |
| 2 | | | 2 | | 4 | 6 | 1 | | 22 |
| 3 | | | | 5 | | 24 | | | |
| 4 | | | | | | 7 | | | 19 |
| 5 | | | | | | 9 | | | |
| 6 | | | | | 12 | 39 | | | |
| 7 | | | | | | | 24 | | |
| 8 | | | | | | | | 25 | 1 |

| | Fisherface recognizer by using eye images | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 5 | | | | | 3 | | |
| | | 7 | 7 | 2 | 19 | | |
| | | 20 | 5 | | 4 | | |
| | | | 26 | | | | |
| | | | | | 9 | | |
| | | 24 | | | 27 | | |
| | | | | | | 24 | |
| | | | | | | | 26 |

| | LBPH recognizer by using eye images | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 5 | | | | 3 | | | |
| | | | | 24 | | | 11 |
| | | 19 | 4 | 6 | | | |
| | | | 26 | | | | |
| | | | | 9 | | | |
| | | | | 51 | | | |
| | | | | | | 24 | |
| | | | | | | | 26 |

**Figure 9.** Confusion matrices of face recognizers for eye area images

## Conclusion

In real life face recognition systems like employment tracking systems, training images' dates are different from test images' dates. However, in literature, face recognition systems are trained and tested from the same databases. It can be estimated that, the accuracy rates of literature are higher than the accuracy rates of the real life applications. To investigate this, the accuracy rates of face recognition methods trained and tested from randomly images compared with the accuracy rates of face recognition methods trained and tested from different date images are compared by using different three methods in this study. It is found that, the accuracy rates of images selected randomly are high in all methods. On the other hand, accuracy rate of trained and test from different date images is low. Therefore it can be said that, the accuracies in real life applications are not high as to be in literature. Afterwards, instead of face images, the use of eye area images is investigated in order to increase the accuracy in real-life recognition systems in this study. The eye area image prediction accuracy rates are higher than the face image estimates for all three different recognizing methods. This can be due to some changes like hair, beard or mouth opening are not affect eye area images. Also, since eye detections can be made from only the front view face images, they have a more limited positioning and this could be increased the number of accuracy predictions. In future identification systems, more specific regions of the face instead of the whole face image, can be used for identification with the help of increasing digital resolution qualities.

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[4] IEEE Standard 519-1992, Recommended practices and requirements for harmonic control in electrical power systems, *The Institute of Electrical and Electronics Engineers*, 1993.

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| 10 | Authors' affiliations, Section titles, references, tables, table names, first letters in table captions,figure captions, footnotes, text subscripts, and superscripts | **Abstract** | |
| 12 | Main text, equations, Authors' names, [a] | | *Subheading (1.1.)* |
| 24 | Paper title | | |

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- ❖ All necessary files have been uploaded

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• All references mentioned in the Reference list are cited in the text, and vice versa

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‡ Corresponding Author; Second Author, Postal address, Tel: +90 312 123 4567, Fax: +90 312 123 4567,corresponding@affl.edu

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**Abstract-** Enter an abstract of up to 250 words for all articles. This is a concise summary of the whole paper, not just the conclusions, and is understandable without reference to the rest of the paper. It should contain no citation to other published work. Include up to six keywords that describe your paper for indexing purposes. Define abbreviations and acronyms the first time they are used in the text, even if they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title unless they are unavoidable.

**Keywords-** Keyword1; keyword2; keyword3; keyword4; keyword5.

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Authors are requested write equations using either any mathematical equation object inserted to word processor or using independent equation software. Symbols in your equation should be defined before the equation appears or immediately following. Use “Eq. (1)” or “equation (1),” while citing. Number equations consecutively with equation numbers in parentheses flush with the right margin, as in Eq. (1). To make equations more compact, you may use the solidus ( / ), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use an dash (–) rather than a hyphen for a minus sign. Use parentheses to avoid ambiguities in denominators. Punctuate equations with commas or periods when they are part of a sentence, as in

$$C = a + b \tag{1}$$

Section titles should be written in bold style while sub section titles are italic.

## 3. Figures and Tables

### *3.1. Figure Properties*

All illustrations must be supplied at the correct resolution:

- Black and white and colour photos - 300 dpi
- Graphs, drawings, etc - 800 dpi preferred; 600 dpi minimum
- Combinations of photos and drawings (black and white and colour) - 500 dpi

In addition to using figures in the text, Authors are requested to upload each figure as a separate file in either .tiff or .eps format during submission, with the figure number as Fig.1., Fig.2a and so on. Figures are cited as “Fig.1” in sentences or as “Figure 1” at the beginning of sentence and paragraphs. Explanations related to figures should be given before figure. Figures and tables should be located at the top or bottom side of paper as done in accepted article format.

Figure 1. Engineering technologies.

Table captions should be written in the same format as figure captions; for example, “Table 1. Appearance styles.”. Tables should be referenced in the text unabbreviated as “Table 1.”

Table 1. Appearance properties of accepted manuscripts

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## Acknowledgements

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## References

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