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CONTENTS

CHAPTER 1

MULTI-CRITERIA DECISION-MAKING METHODS – APPLICATIONS IN TEXTILE AND APPAREL INDUSTRY[1]

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1 This book chapter was produced from Öykü Ceren BULUR's Master's Thesis titled "Application of Multiple Criteria Decision-Making Methods For Selection of Subcontracting Workshop of Apparel Companies", which she prepared in the Marmara University Institute of Pure and Applied Science, Textile Engineering Program in 2019. The thesis supervisor is Assoc. Prof. Dr. Mahmut KAYAR.

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INTRODUCTION

Decision-making is an important concept that we encounter in many subjects from meeting a simple need to choosing the location of a factory. So much so that regardless of gender, profession, educational status or income status, it is an activity that every person performs in almost every subject, in all processes from daily life to business life. Due to this importance, the issue of decision-making has been the focus of attention of researchers from past to present and different studies have been carried out in almost every field on this subject.

Since multi-criteria decision-making is a wide subject, in this chapter, only decision-making (DM), types of DM, DM situations and elements, factors affecting DM, DM process, Multi-Criteria Decision-Making (MCDM) and MCDM techniques and the applications of these techniques in apparel and textiles are included.

1. GENERAL CONCEPTS FOR DECISION MAKING

1.1. Decision-Making

Decision-making is an integral part of daily life and concerns large groups and societies, from individual life to global organizations. Decision-making examines situations ranging from simple to complex and involving multiple criteria [1].

Decision-making is a concept that is constantly evolving with the change of thought structures that have existed for centuries. Decisions taken for a single purpose, in the beginning, have started to move towards systems aimed at providing more than one purpose, with the differentiation of goals and preferences [2].

Decision-making is the process of choosing one or more of the available options, together with a set of criteria, in order to solve a particular problem and achieve the desired goal [3].

By another definition, decision-making is the process whereby an individual, group or organization reaches conclusions about what future actions to pursue given a set of objectives and limits on available resources [4].

The decision-making process is an indispensable and inseparable part of human life, and people are faced with the decision-making situation on every issue, from the simplest to the most complex. People have to choose from many options in order to meet both their personal and social needs throughout their lives. This selection work that needs to be done is called “decision making” [3].

Many definitions of the concept of decision-making have been made by various researchers. Some of these are given below.

- is choosing one of the actions according to the optimization criteria [5].
- is the process of choosing one or more of the alternatives that are most suitable for the purpose or purposes [6].
- is an action that is consciously chosen from among the available options to achieve a desired outcome.
- is to choose the most appropriate one from various possible activities in order to achieve a goal [7].
- is the task of making choices when events and events with multiple dimensions are present [8].

The decision-making process is when the decision-maker is faced with a number of different options, he can choose the most suitable one among them [9].

A final judgment given by thinking about a business or problem is called a "decision". A decision is the undertaking of behaviour aimed at developing satisfactory situations for particular parts of matters [10].

According to another definition, a decision is defined as a series of dynamic factors and activities that begin with the identification of the necessary elements for action and end with the formation of a specific judgment for action [11].

Despite the confusion of the definitions of "decision" and "decision-making", there is a definite difference between them. This difference is that the decision-making behaviour has a certain process. Generally speaking, decision-making is defined as choosing among available alternatives. If there is only one option to choose from, it is not possible to talk about decision-making here.

In order for decision-making behaviour to take place, the following conditions must be met:

- There should be a difficulty (a difficult situation) that reveals the need to make a decision and this difficulty must be felt by the individual.
- There should be more than one option to resolve the difficult situation. If there is only one option, it cannot be mentioned in the decision-making situation.
- The individual should have the freedom to choose one of the available options [12].

1.2. Types of Decision – Making

During the execution of various activities in organizations and in the management process, different decisions may be taken. Accordingly, organizational management can choose various types of decisions in the face of various situations and events [13].

Different classifications of decision making types are given in Table 1.

Table 1. *Classifications of decision making types*

Types of Decision-Making	**Subgroups**				
Decisions by Recurrence	Programmed	Unprogrammed			
Decisions According to Management Levels	Corporate	Strategic	Managerial	Operational	
Decisions According to Their Structures	Manager-Based	Based on the Parliamentary System	Compromising decision for reconciliation	Decisions Based on Persuasion System	
Decisions According to the Time Covered	Short Term	Medium Term	Long Term		
Decisions According to the Business Function They Are Related to	-	-			
Decisions According to the Method Used and Source of Information	Based on Past Experience	Based on Trial	Based on Research and Analysis		
Decisions in Terms of Knowledge Based on	Under Certainty	At Risk	Under Uncertainty	With partial (incomplete) information	Competitive (game theory)
Decisions According to Scope and Importance	Whole Organization	A part of the Organization			
Decisions in Terms of the Decision-Making Body	Individual	Group			
Decisions According to the Place of the Decision-Maker in the Organization	Command Decisions	Staff Decisions			
Decisions by Importance	Primary	Secondary			
Decisions According to Organizational Life Cycle	Regarding the Establishment Phase	Regarding the Development Phase	Regarding the Termination Phase		
Decisions According to the Forms of Giving	Oral	Written			
Decisions Based on Connectivity	Static	Dynamic			
Decisions in Terms of Qualifications	Announced	Unexplained			

1.3. Decision-Making Situations (Conditions)

While examining the decision-making problem, the decision-maker should examine the environment in which he made the decision, and determine in which environment he made a decision. The decision environment depends on the decision maker's knowledge of the natural states and the realization of these natural events. This distinction, which classifies the states of nature, their realization relationship, and the decision environment, is as follows.

- Decision-making in an environment of certainty,
- Decision-making under risk,
- Decision-making under uncertainty,
- Decision-making with partial (incomplete) information,
- Competitive decision-making (game theory) [14-16].

1.3.1. Decision-Making in an Environment of Certainty

If the event that will occur is known with certainty, if there is only one event in the decision matrix, the problems are examined under the decision problem in case of certainty. That is, the probability of the expected event occurring is 1. This type of decision-making problem has a deterministic structure. Problems with only one event in the decision matrix and certain outcomes are classified as decision problems in case of certainty. There is full information about each selection. The decision maker has reliable information about the outcome. Certainty also indicates the state of being aware of the decision maker. The probability of the event occurring must be assumed to be 1. With decision-making in an environment of certainty, the decision-maker can easily choose the option that best suits his/her purpose [17].

For example, the supplier selection decision is also a decision under certainty.

1.3.2. Decision-Making at Risk

In decision-making in a risk environment, there are many different conditions related to a particular decision to be taken. The results of each strategy under all conditions depend on certain probabilities. In such cases, it cannot be predicted how the strategies will yield results. The realization of results depends on certain probabilities. Decision-making by considering probabilities is called decision-making in a risk environment [18].

1.3.3. Decision-Making under Uncertainty

Decision-making under uncertainty is similar to decision-making under risk. As with decision-making at risk, outcomes relate to alternative actions based on natural situations. In an environment of uncertainty, the probability distribution on which natural states depend is either unknown or undetectable. This lack of information has given rise to the following new criteria for the analysis of the decision problem. In this case, the decision maker decides using criteria [19].

- Wald's Maximin criterion
- Hurwicz's criterion
- Maximax criterion
- Savage's minimax regret criterion
- Laplace's insufficient reason criterion [20].

The above criteria vary according to the decision maker's degree of consistency in the face of uncertainty.

1.3.4. Decision-Making with Partial (incomplete) Information

When the distribution of the probability of occurrence of the events (normal, poisson, binomial, etc.) is known, and if there is information about the parameters and characteristics of the distribution (mean, median, skewness, kurtosis), decision-making is in question.

In risky decision problems, the decision maker has a set of preliminary probabilities for which the best guess is. Additional information about events may be needed to make the best decision. This new information can be corrected and preliminary probabilities are updated so that final decisions can be made [17].

1.3.5. Game Theory (Competitive Decision-Making)

Game theory is that in the decision-making process in which at least two people are parties and there is competition, the parties choose the most suitable alternative among the available alternatives.

Competitive problems can be considered under game theory. Today, decision-making processes at all levels, from individuals to companies, local and international institutions and organizations, have turned into a form of strategic thinking. In order to achieve better results and make the best decision, the decision-making units monitor the behaviour of their competitors more closely, collect more information and make decisions based on this information. The scientific evaluation of this process is the field of game theory.

The game theory approach can also be used in solving economic problems. The desire to take the most appropriate decision, especially under competitive conditions, has brought game theory to a level that can be applied successfully in all fields of social sciences. Today, game theory is widely applied in solving problems in making economic, political and military decisions [21].

1.4. Decision-Making Elements

A decision-making process consists of the following elements.

- Decision-Maker: A person or group that makes a choice from among the available options.
- Purpose: It covers the goals that the decision maker will achieve through his actions.
- Decision Criteria: These are the values that the decision maker uses while making a choice. Maximization of income, profit and benefit; includes minimizing costs, expenses, and the like.
- Strategies: It covers different alternative actions that the decision maker can choose. It depends on the resources under the control of the decision maker and can be controlled.
- Events: Includes factors that are not under the control of the decision maker. It depends on the environment and events that affect the decision maker's strategies.
- Result: Shows the value that will appear after each event [22].

1.5. Factors Affecting Decision-Making

1.5.1. Anxiety About Making Good Decisions

Managers want to make consistent and correct decisions in line with their possibilities. Because this is their most important capital. This situation creates great pressure on the managers and they experience the anxiety of not making good decisions. Because the closer you get to the fundamental decisions, the greater the responsibilities and difficulties. Such pressures and concerns inevitably affect the quality of the decisions to be made by the decision maker [23].

1.5.2. Decision-Making Environment

Decision makers have to follow and take into account the events and developments in both the internal and external environment in order to make good decisions. The external environment includes the social, political, economic and cultural conditions of the society, state, nation and the

world. The internal environment consists of physical elements, organizational structure, decision-making behaviours, and unpredictable features of the interaction between decision-makers and employees [2].

1.5.3. Time

One of the factors that significantly affects the quality of the decision is the time available in the decision making process. Decision makers have to make most of their decisions within the time frame limited by others. In the decision-making process, the decision maker may not be able to gather enough information or evaluate additional options due to time pressure [24].

1.5.4. Decision-Maker or Decision-Makers

The decision maker represents the person or group that makes a choice from among the available options. The decision maker may be a person or a group, but it is necessarily human. The person at the centre of the decision-making process, which is also seen as a psychological process, is the person who thinks, evaluates and takes action with his own will in order to react to the situation encountered.

The decision-making process is highly influenced by the psychological characteristics of individuals such as perception, motivation and comprehension, as well as inter-individual relations and interactions. Here, the individual should be considered as someone whose motives, perceptions, attitudes and values are tried to be influenced by the organization, not alone [21].

1.5.5. The Risk of the Decision

The degree of damage caused by a wrong decision on any subject is also one of the factors affecting decision making. This is referred to as the risk of the decision. When decision makers make a decision, they consciously or unconsciously take this risk. Whether this risk is tolerable or not will affect the decision [2].

1.5.6. Psychological Factors

Since decision making is an important thought process, there are many psychological factors that affect this process. Some of these psychological factors affect the decision maker's ability to evaluate and may cause some prejudices in the decision maker. One of the psychological factors is the social environment in which the decision makers are located. The nation, social class or organization that the decision maker belongs to can affect his decision.

Another factor is that the decision maker is influenced by the knowledge and values of organizations or groups with the same prestige outside

his own organization. Another psychological factor is the dilemma style of thinking. One of the prejudices that affect the evaluation in the decisions made is that people generally perceive objects and problems that are visible, tangible, close to them better than those at a distance [21].

1.5.7. The Amount and Type of Information Available

Having the desired and sufficient information about the subject to be decided is a desired situation for all decision makers. However, this may not always happen. The amount and variety of information available is insufficient when making many decisions. This is a very risky situation for the decision to be made. Some simple decisions may not require extensive information, but complex situations may require detailed information. On the other hand, the available information for different problems may be large in quantity, but the variety of this information may not be helpful in the decision-making process. As a result, the decision-making process is affected by the amount and variety of information available [25].

1.5.8. Previous Decisions

Decisions are generally taken one after the other and each decision affects the next decision. For this reason, some decisions are made taking into account the preferences that have been concluded before. For example, if a business has made an investment decision before, it will not be able to return from this decision and its decisions will depend on this investment. Because a certain resource has been allocated for the investment and expenditure has been made [21].

1.5.9. Written Rules

Some businesses have specific written rules and procedures to apply in different situations. For this reason, the decision maker is limited by these rules and procedures while making some decisions. For example, if a decision maker wants to make a decision about a staff member, he cannot go beyond the contractual clauses he signed with the union [25].

1.6. Decision-Making Process

1.6.1. Identifying the Purpose or Problem

The first step in decision making is determining the purpose and defining the problem. It is a stage where the decision maker should accept the situation to be decided in line with the data received and be sensitive [26].

1.6.2. Examination of the Purpose or Problem

After the decision-making purpose is determined, the reasons, char-

acteristics, and situations to be encountered should be analysed and examined. Such a review would be healthier for problem identification [27].

1.6.3. Determination of Solution Alternatives

After the purpose of decision-making is determined and defined, alternatives are determined. A detailed examination of the objectives may reveal alternatives that were not initially seen. This is one of the most important benefits of the decision-making approach. In addition, some research on creativity has led to the emergence of some new techniques. This has given a chance to use new alternatives [22].

In the alternative identification phase, a list of alternatives to solve the problem should be made. An alternative or option is a way of using resources to achieve the goal. If there is only one alternative, there is no decision-making. Because decision making represents a choice. The listed alternatives show the ways to choose [27].

1.6.4. Evaluating Alternatives

Developed solution alternatives are evaluated in terms of technical feasibility, cost, resource consumption, probability of success and results. Alternatives are ranked according to these evaluations [26].

1.6.5. Determination of Selection Criteria

Selection criteria are needed to be able to choose from among the listed alternatives. The selection criterion expresses which features of the alternatives will be used when choosing a decision. For example, the cost element is a selection criterion. In this case, the alternative with the lowest cost will be chosen among the alternatives [22].

1.6.6. Selection of the Most Suitable Alternative

In this final stage, the actual decision is made for the current problem. The most suitable alternative is chosen among the alternatives. Here, the most rational and correct approach is to choose the most suitable alternative, not the best alternative. The most appropriate criterion is the most efficient and cheapest. It can be difficult to find the most suitable one among the alternatives. First of all, it is necessary to know all the solutions. For this reason, extensive research should be done. Therefore, the decision maker needs time, energy, knowledge and support from experts in matters other than his/her expertise [23].

2. MULTI-CRITERIA DECISION-MAKING METHODS

Multi-criteria decision making (MCDM) is the branch of decision

theory that includes the most widely used methods. It includes methods that enable choosing among alternatives, grouping or ranking alternatives by evaluating more than one decision criteria [28]. Multi-criteria decision-making methods are methods that are based on qualitative and quantitative criteria, can be easily applied, and offer common solutions for different problems when making a decision for a problem. Although there are various examples that it is used for solving many problems in businesses, it is also frequently used in determining product, employee and business performance, and in other performance evaluations [29].

MCDM problems are classified as multi-attribute decision-making (MADM) and multi-objective decision making (MODM). In MADM problems, the number of alternatives is predetermined and the success levels of each of these alternatives are determined. In MADM problems, decisions are made by comparing the qualities of each alternative. In MODM problems, the number of alternatives is not known beforehand, and the aim is to determine the best alternative. On the other hand, in quantitative decision making techniques, the number of alternatives that will give the ideal solution is not known beforehand. For this reason, the optimization technique to be used should be one of the MODM methods [26].

As explained above, the concept of MCDM is divided into two general categories: MADM and MODM (Figure 1). This distinction is also divided into two as individual and group decision-making processes. Afterwards, it is also divided into decision making in an environment of certainty and uncertainty. The distinction between MADM and MODM depends on evaluation based on the goals and objectives of the criteria [30]. For example; supplier selection problem is in the category of multi-qualified decision making under the concept of MCDM. It is an individual decision-making process under MADM and a decision-making problem under certainty.

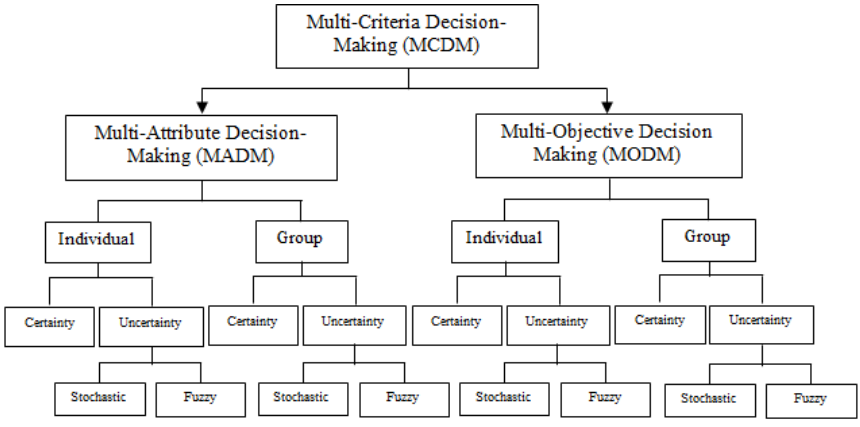

Figure 1. *Classification of MCDM problems [30].*

Some commonly used multi-criteria decision making methods are listed below.

- TOPSIS (Technique for Order Preference by Similarity to Ideal Solution),
- AHP (Analytic Hierarchy Process),
- ANP (Analytic Network Process),
- ELECTRE (Elimination and Choice Translating Reality)
    - ELECTRE II
    - ELECTRE III
    - ELECTRE IV
- PROMETHEE I ((Preference Ranking Organization Method for Enrichment Evaluations) - Partial Ranking))
    - PROMETHEE II (Complete Ranking)
    - PROMETHEE III (Ranking Based on Intervals)
    - PROMETHEE IV (Continuous Case).
    - PROMETHEE V (MCDA Including Segmentation Constraints)
    - PROMETHEE VI (Representation of the Human Brain).
- VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje),
- MOORA (Multi-objective Optimization By Ratio Analysis),
    - MULTIMOORA (Multiple Objective Optimization on the Basis of Ratio Analysis Plus Full Multiplicative Form),
- MACBETH (Measuring Attractiveness by a Categorial Based Evaluation Technique),
- MAUT (Multi-Attribute Utility Theory),
- UTA (Utility Additive Analysis),
- UTADIS (Utilities Additives Discriminants),
- DEA (Data Envelopment Analysis),
- GP (Goal Programming),
- GRA (Grey Relational Analysis),
- WSM (Weighted Sum Model),

- SMART (Simple Multi-Attribute Ranking Technique),
- MAVT (Multi-Attribute Value Theory),
- SAW (Simple Additive Weighting),
- WTM (Weighted Product Model),
- QFD (Quality Function Deployment)
- FDM (Fuzzy Decision Making),
- SWARA (Step-Wise Weight Assessment Ratio Analysis),
- WASPAS (Weighted Aggregated Sum Product Assessment)
- DEMATEL (The Decision Making Trial and Evaluation Laboratory) [21, 31-35].

The main MCDM methods are listed above, and brief information is given below about the most widely used methods and methods used in the field of textile and apparel.

2.1. TOPSIS Method

TOPSIS method was developed by Yoon and Hwang in 1981 as an alternative to the ELECTRE method and is one of the most widely used methods. TOPSIS based on the fundamental premise that the best solution has the shortest distance from the positive-ideal solution and the longest distance from the negative-ideal one. TOPSIS method assumes that each criterion has a regularly increasing or decreasing utility trend. Therefore, it is easy to identify ideal and negative-ideal solutions. The Euclidean distance approach aims to evaluate the relative closeness of alternatives to the ideal solution. Thus, by comparing these relative distances, the order of preference of the alternatives can be deduced [36-38].

Fuzzy TOPSIS (FTOPSIS): It is an MCDM method that works with fuzzy logic.

2.2. AHP Method

AHP is one of the most popular and widely employed multi-criteria decision-making methods. Developed by Professor Thomas L. Saaty in the 1970s, the AHP method is a decision-making method used for solving complex problems involving more than one criterion. In this technique, the processes of rating alternatives and aggregating to find the most relevant alternatives are integrated. AHP allows decision-makers to model complex problems in a hierarchical structure, showing the relationship between the problem's main objective, criteria, sub-criteria and alternatives.

The most important feature of AHP is that it includes both objective and subjective thoughts of the decision-maker in the decision-making process. The aim of the AHP method is to ensure that the decision-making process is concluded in the most effective way, by placing the related priorities on a scale for the given options, taking into account the intuitive judgments of the decision-maker and the consistency of comparison. This approach supports the judgments of the decision-maker based on his knowledge and experience.

The strength of the AHP is that it can organize countable and uncountable factors in a systematic way and offers a simple and effective way of the decision-making process by considering all factors. The technique is employed for ranking a set of alternatives or for the selection of the best in a set of alternatives. The ranking/selection is done with respect to an overall goal which is broken down into a set of criteria. In addition, the AHP method is used together with operational techniques such as integer programming, goal programming, and dynamic programming in many studies [39-40].

Fuzzy AHP (FAHP): It is an MCDM method that works with fuzzy logic.

2.3. ANP Method

ANP method, which can be considered the continuation of the AHP method, offers more effective and realistic solutions for complex decision-making problems. ANP has all the positive features of AHP, including simplicity, flexibility, simultaneous use of quantitative and qualitative criteria and the ability to review consistency in judgments.

ANP computes complex relationships between decision elements through the replacement of a hierarchical structure with a network structure. ANP provides the opportunity to evaluate all relationships in a systematic way by incorporating all kinds of interactions, dependencies and feedback in the decision-making process into the model. The superiority of the supplier selection method created using the ANP method is that decision-making problems involving complex interactions can be easily expressed without being bound by any hierarchy. The method allows not only pairwise comparisons of sub-criteria under certain main criteria but also the independent comparison of all sub-criteria that interact with each other. In other words, in a network, feedback and interconnection are possible between clusters [41-43].

2.4. ELECTRE Method

ELECTRE method is a multiple decision-making method that was first introduced by Bernard Roy in 1966. The ELECTRE method is based

on pairwise superiority comparisons between alternative decision points for each evaluation factor. At the same time, this method is based on a dominance or dominance relationship. A measure of efficiency and importance is determined for each criterion. Each option is graded based on the determined efficiency measures. The decision maker must define compliance and incompatibility limits.

The most important advantages of the technique are that it can be applied to a great variety of real-world problems and also, the possibility of taking into account the qualitative nature of the criteria, imperfect knowledge and heterogeneous scales. One disadvantage is related to the decision-maker needing to define a set of initial parameters that, most of the time, increase the decision-makers cognitive effort [44-46].

2.5. PROMETHEE Method

PROMETHEE method is a multi-criteria prioritization method developed by J.P. Brans in 1982. The family of PROMETHEE is an outranking method that aims at the evaluation of criteria in a qualitative and quantitative way, it is characterized by three pillars;

1. the enrichment of the preference structure involving different preference functions,

2. the enrichment of the dominance relation between alternatives for each criterion and

3. the decision aiding after the partial and complete ranking.

Six major preference functions can be used depending on criteria characteristics, these preference functions withdraw criteria scaling effect which is one of the main advantages of this method.

PROMETHEE method was developed based on the difficulties in the implementation phase of the existing methods in the literature and has been used in various studies on supply management until today. The success of the methodology is basically due to its mathematical properties and its particular friendliness of use. [47-49].

2.6. VIKOR Method

VIKOR (VIseKriterijumska Optimizacija I Kompromisno Resenje) method was developed by Opricovic and Tzeng for multi-criteria optimisation in complex systems.

The method facilitates the selection using a compromise ranking list and weight stability intervals from a set of alternatives; the process employs a multi-criteria ranking index based on particular measurements of

closeness to the ideal solution. The method is an effective method for ranking alternatives and finding a compromise solution from a set of alternatives, to help the decision maker reach a definitive solution when there are conflicting criteria.

The compromise solution obtained will be accepted by the decision maker as it will provide maximum group benefit for the majority and minimum regret for dissenters. The VIKOR method is often used in line with traditional methods in the relevant literature such as the TOPSIS, the Preference Ranking.

VIKOR method, similarly to the TOPSIS method, is based on distance measurements. In this approach a compromise solution is sought. [50-53].

2.7. MOORA Method

MOORA method was first introduced to solve complex decision-making problems by Willem Karel M. Brauers and Edmundas Kazimieras Zavadskas in their study "Control and Cybernetics" in 2006.

MOORA method helps decision-makers in the process of simultaneously optimizing 2 or more conflicting criteria or objectives subject to certain constraints.

The advantages of this method are that all the objectives are considered and all interactions between alternatives and objectives are considered simultaneously, not piecemeal and that it uses non-subjective non-directional values instead of subjectively weighted normalization [54-56].

2.8. DEMATEL Method

DEMATEL method is a kind of structural modelling approach used to analyse different factors affecting a system and to better understand the cause-effect relationships between these factors. The DEMATEL method, which is based on graph theory, provides the solution and analysis of problems with the visualization technique.

DEMATEL can be applied to confirm the existence of a relationship/interdependence among components or reflect the relative level of relationships within them. Thus, the DEMATEL method is one of the most effective methods used in solving especially complex and nested problem groups. Thanks to the method, cause and effect relationships between all factors affecting a problem can be easily determined and analysed.

DEMATEL method not only transforms the relationships between factors into a cause-and-effect group but also finds the critical factors of a complex system with the help of an impact relationship diagram. [57-61].

2.9. QFD Method

QFD is basically a planning process with a quality approach to new product design, development, and implementation driven by customer needs and values. Quality function deployment (QFD) is a structured process that uses a visual language and a set of interlinked engineering and management charts to transform customer requirements into design, production and manufacturing process characteristics. The "voice of the customer" is the term to describe these stated and unstated customer needs or requirements.

QFD approach uses a matrix format that looks like a house and, hence, it is also known as the "House of Quality" (HoQ). The method aids in making cognizant decisions about the voice of customers. The aim of QFD is to translate objective and even subjective quality criteria into objective quality criteria that can be quantified and measured. It is a complementary approach for indicating how and where priorities are to be assigned in product development.

The HoQ (also known as the product planning matrix) is a primary tool used in QFD and usually comprises nine different sections or so-called Rooms [62-65].

2.10. DEA Method

DEA (Data Envelopment Analysis), incepted in 80s, has emerged as a popular decision-making technique, for determining the efficiency of similar units.

DEA is a linear programming methodology that empirically quantifies the relative efficiency of multiple similar entities or DMUs. The DMU is the homogeneous entity responsible for the conversion of inputs into outputs.

DEA models can be oriented to inputs or to outputs. The objective of models oriented to inputs is to determine how many inputs may be reduced to operate efficiently to maintain the same output levels.

DEA is a relatively new "data-oriented" approach for evaluating the performance of a set of peer entities called Decision Making Units (DMUs) which convert multiple inputs into multiple outputs. Because it requires very few assumptions, DEA has also opened up possibilities for use in cases that have been resistant to other approaches because of the complex (often unknown) nature of the relations between the multiple inputs and multiple outputs involved in DMUs. [66-69].

3. APPLICATIONS OF MCDM TECHNIQUES IN APPAREL AND TEXTILE

In the literature, it is seen that MCDM methods are widely used in different areas of the textile and apparel industry. According to the data obtained as a result of the literature review, it has been seen that MCDM methods are applied for different purposes in textile and apparel. Below are the problems in which MCDM methods are used in textile and apparel and the studies related to this use are given.

- *Studies Related Supplier Selection*

Kara and Ecer used the AHP-VIKOR integrated method for supplier selection for a textile company in Uşak [70].

Kargı used the fuzzy TOPSIS method in the selection problem of the yarn supplier to be used by a textile company [71].

Güleş et al. selected the fabric supplier for a ready-made clothing company in Konya using the AHP method [72].

Öztürk et al., in a textile company operating in Bursa, selected the supplier for the yarn to be used in combed cotton production using the AHP method. In this study to solve the supplier selection problem, they evaluated 7 main criteria and 13 sub-criteria related to them [73].

Chen conducted a study in Taiwan's textile industry to manage suppliers to increase the marketability of products. It has been seen that they consider 4 main criteria and 8 sub-criteria, namely quality, cost, technology and production and organizational management, to select and evaluate suppliers [74].

Chan and Chan used the AHP method to solve the supplier selection problem in a clothing company [75].

Tayyar and Arslan have solved the problem of choosing the best subcontractor company that places the orders of world-famous brands in ready-made clothing with AHP and VIKOR methods [76].

Reyhan has benefited from the TOPSIS method in the selection of the contract slaughterhouse in a ready-made clothing business. In his study, he determined 9 criteria and evaluated 11 cutting workshops in total [77].

Arıkan selected a subcontractor for a textile company with the AHS (Analytical Hierarchy Process) method [78].

Dursun used the Fuzzy AHP method for supplier selection in the textile industry [79].

Sinan used the AHP method for supplier selection in a garment company [80].

Karataş Cevizci used MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique), VIKOR and TOPSIS methods in the analysis of supplier selection in apparel businesses with the help of multi-criteria decision support systems [81].

Arslan used fuzzy AHS and fuzzy TOPSIS methods for the best subcontractor selection in the ready-made clothing industry [82].

Yücel used AHP, TOPSIS and VIKOR methods in his master's thesis titled "The Most Appropriate Supplier Selection in the Textile Industry and a Software Application with Multi-Criteria Decision-Making Techniques [83].

Bulur and Kayar used TOPSIS and AHP methods in the selection of subcontractor workshops. Mumcu et al. estimated the results of the work distribution made by the TOPSIS method, which is frequently used in the distribution of work to subcontractor workshops, using the Artificial Neural Networks Method (ANN) [84,85].

- *Studies Related Establishment Location Selection*

Akyüz and Soba used the ELECTRE method in the selection of 3 alternative establishment locations for a textile industry enterprise to be established in Uşak [86].

Ertuğrul and Karakaşoğlu, fuzzy AHP and fuzzy TOPSIS methods were compared in the location selection of a textile company in Turkey. The differences and similarities of both methods are discussed [87].

Alp and Gündoğdu used AHP and fuzzy AHP methods in the selection of the establishment location of a company that produces ready-made clothing, and they revealed the effect of turbidity on the results [88].

Acar used the AHP method in the selection of the optimal establishment location in the ready-made clothing business [89].

- *Studies Related Financial Performance Analysis*

Konak et al. analyzed the financial performances of 23 companies operating in the textile sector, whose stocks were traded in Borsa Istanbul in the period of 2010-2015, with TOPSIS and MOORA methods, and achieved success scores and ranked them with the obtained scores [90].

Deng et al. examined the performances of 7 companies operating in the field of textiles under 4 financial criteria. They used the TOPSIS method in their study [91].

Temizel and Bayçelebi have made a performance ranking of the companies operating in the textile sector according to their selected financial ratios, and they have used the TOPSIS method to obtain the ranking [92].

- *Studies Related Supplier Performance Evaluation*

Durdudiler used AHP and fuzzy AHP methods in supplier performance evaluation in the retail industry [93].

Yılmaz used DEA, TOPSIS and AHP methods to evaluate the performance of apparel suppliers [94].

Sinan used the AHP method for supplier evaluation in a garment company [80].

- *Study Related Customer Selection*

Acar and Güner used the TOPSIS method to select customers for an apparel business [95].

- *Study Related Machine Selection*

Ertuğrul used the fuzzy AHP method in selecting the best textile machine in a textile company [96].

- *Study Related Sustainability Performance Evaluation*

Acar, Kılıç and Güner examined the performance evaluation of a corporate company in the textile sector, based on environmental factors, in terms of sustainability. The sustainability performance of the company was evaluated by examining the data obtained from the annual reports of the company with the TOPSIS method [97].

- *Study Related Supply Chain and Stock Management*

Tanriverdi used ABC analysis and AHP methods in supply chain and stock management in a textile company and compared these methods [98].

- *Study Related Production Process Determination*

Baylavlı used the AHP method to determine the most appropriate production process for the production of men's shirts [99].

- *Study Related Personnel Selection*

Şener used the AHP method in the personnel selection problem in the textile sector [100].

- *Study Related Comparison of Retailers' Performance Characteristics*

Aydın used SCOR (Supply Chain Operations Reference) and AHP methods to compare the performance characteristics of ready-to-wear retailers [101].

- *Study Related Internal Benchmarking in the Retail Sector*

Aksoy used QFD (Quality Function Deployment) and AHP methods

for internal benchmarking in the apparel retail industry [102].

- *Study Related Evaluation of Export Activities*

Öztürk conducted a study of evaluating the export activities of Turkish textile and ready-made clothing companies in 2012 using Data Envelopment Analysis and AHP methods [103].

- *Study Related Criteria Affecting Reverse Logistics System Design*

Güzel made a decision analysis on the criteria affecting the design of reverse logistics systems in the textile industry and used the AHP and DEMATEL methods in this study [104].

Again, based on the above studies, the following table (Table 2) can be created regarding the purposes for which MCDM methods are used.

Table 2. *Distribution of MCDM Techniques on the basis of intended use in Textile and Apparel*

Purposes	**Methods**								
	TOPSIS **F**TOPSIS	AHP **F**AHP	VIKOR	MACBETH	MOORA	ELECTRE	DEA	QFD	DEMATEL
Supplier Selection	xx	xx	x	x					
Establishment location selection	xx	xx				x			
Financial Performance Analysis	x				x				
Supplier Performance Evaluation	x	xx					x		
Customer Selection	x								
Machine Selection		x(F)							
Sustainability performance evaluation	x								
Supply chain and stock management		x							
Production Process Determination		x							
Personnel Selection		x							
Comparison of retailers' performance characteristics		x							
Internal benchmarking in the retail sector		x						x	
Evaluation of Export Activities		x					x		
Affecting Reverse Logistics System Design		x							x

According to these results, it is seen that MCDM techniques are mostly used in supplier selection. This was followed by establishment location selection, financial performance analysis and supplier performance evaluation, respectively.

When Table 2 is examined, it is seen that AHP and FAHP methods are used for almost every purpose. TOPSIS and FTOPSIS are the most used methods after AHP.

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CHAPTER 2

TIME SERIES PREDICTION FROM COMMERCIAL AIRCRAFT ACCELERATION SENSOR DATA WITH DEEP NEURAL NETWORKS: A BENCHMARK STUDY

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1. Introduction

Optimizing the flight routes of Aerial Vehicles (AVs) used for different purposes and ensuring the safety of these AVs has been an important issue for researchers for years. Since the beginning of the 2000s, researchers have been performing the optimization and safety processes of aircraft by using sensor data. In the aforementioned studies, in general, various data are obtained from many sensors in Aerial Vehicles, and the interpretation of these data is commonly carried out by machine learning algorithms.

In the literature, there are many studies that process time series data obtained from sensors in AVs and interpret these data with machine learning algorithms (Cao et. al, 2018; Tong et. al, 2018a; Tong et. al, 2018b; Wang. et al, 2019; Alkhamisi & Mehmood, 2020; Memarzadeh et. al, 2020; Balakrishnan et. al, 2021; Lee et. al, 2021; Memarzadeh et. al, 2022). In (Cao et al., 2018), researchers focused on the optimization of the LSTM model structure and parameters and feature extraction, in order to avoid the big problems that may arise during the estimation of the large amount of data obtained by the engineers during the test flights of the aircraft. In one of the studies conducted by Tong et al. in 2018, a new deep learning approach was proposed to predict future flight landing speed (Tong et. al, 2018a). In the study carried out using Quick Access Record (QAR) data, it has been shown by experimental studies that the proposed LSTM based deep learning model showed high performance compared to the methods of that period. In another study conducted by Tong et al. in 2018, the LSTM-based recurrent neural network model was used for Aircraft hard landing prediction, one of the IoT applications in the aviation field (Tong et. al, 2018b). As seen in both studies, LSTM-based systems have shown high performance in solving prediction problems. In the study carried out by Balakrishnan et al., health monitoring of the aircraft engine was carried out by using data from 13 different sensors of a military aircraft. The Whale Optimization Algorithm based Artificial Neural Network (WOANN) method proposed by the researchers within the scope of the study performed much better than 3 different classical artificial neural networks (Balakrishnan et. al, 2021).

Deep learning models are widely used to perform risk prediction in aviation systems (Alkhamisi & Mehmood, 2020; Lee et. al, 2021). A new safety assurance model in which deep learning and machine learning algorithms are ensembled for aviation systems was proposed by Alkhamisi and Mehmood in 2020. In another study conducted for the same purpose, a model in which convolutional neural networks (CNNs) and long short-term memory (LSTM) layers were used together was proposed by Lee et al., and it was aimed to increase the performance in risk prediction with this proposed model (Lee et. al, 2021).

One of the topics that the studies on AVs in the literature focus on is the detection of anomalies in the sensor data (Wang. et al, 2019; Memarzadeh et. al, 2020; Memarzadeh et. al, 2022). Detecting anomalies with a high performance prevents possible damages and financial losses related to AVs. In the study performed by Wang et. al, an LSTM-based model was proposed to detect anomalies in Unmanned Aerial Vehicles (UAVs) and the performance of this model in detecting anomalies in data from sensors was examined (Wang. et al, 2019). In the first study on anomaly detection by Memarzadeh et. al, Convolutional Variational Auto-Encoder (CVAE), an unsupervised deep generative model, was proposed to overcome the anomaly detection difficulty in high-dimensional time series data (Memarzadeh et. al, 2020). In another study conducted by Memarzedeh et al. in 2022 on anomaly detection, a semi-supervised deep learning model was proposed for the detection of anomaly in sensor data (Memarzadeh et. al, 2022).

As seen in the studies mentioned above, the data obtained from the sensors in different aircraft have been interpreted for different purposes (health monitoring, anomaly detection, risk prediction etc.) using machine learning and deep learning algorithms.

Within the scope of this study, sensor data prediction was performed with the body longitudinal acceleration data of the flight sensor data set published by NASA for Flight Operations Quality Assurance (FOQA) studies. For this purpose, the sensor data of five different models using three different deep learning architectures were compared for the prospective estimation and the results were shared with the researchers. In the following sections, information about the deep neural networks, data set, and simulation studies are given and the results are interpreted.

2. Methodology

The block diagram of the study in which deep learning networks are compared for the prediction of acceleration data in flight operational quality assurance (FOQA) dataset is given in Figure 1.

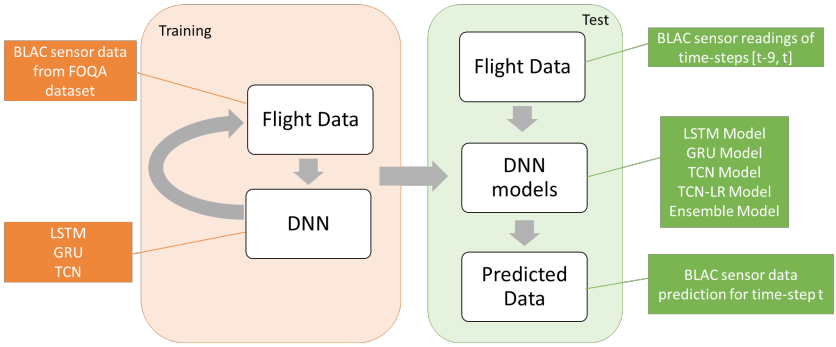

Figure 1. *The block diagram of the benchmark study.*

As seen in Figure 1, firstly, the Body Longitudional Accerelation (BLAC) sensor data, which is found in the flight data (FOQA dataset) collected by NASA, was rearranged. Three deep learning models, Long-Short Term Memory, Gated Recurrent Unit and Temporal Convolutional Network networks, which are widely used in time series predictions, were trained by using these data. In addition to these models, the training of the TCN-LR model, which is using the Leaky ReLU activation function, and the ensemble model, which is a combination of four different deep learning models, was also used on the same data. As a result of this process, the sensor data prediction was completed with the BLAC sensor data in the flight data with five different deep learning models. The test processes of the trained models were carried out by using test the data, 30% of the whole flight data was reserved for testing, and the model prediction performances were compared using three different evaluation metrics.

In the subsections below, detailed information is given about the deep learning models used in the study, and then detailed information is given about the evaluation metrics that will be used to compare the test performances of the models.

2.1. Deep Neural Networks

Deep learning models have been widely preferred in solving time series prediction problems in recent years. The high performance of deep learning models in time series prediction has led researchers to work intensively on this subject and propose new architectures. In this context, information about the three most widely used deep learning models is given in the following subsections.

2.1.1. Long Short-Term Memory

Long Short-Term Memory (LSTM) is a sort of artificial neural network that is commonly used on sequential data and time series prediction problems (Hochreiter & Schmidhuber, 1997). The LSTM has a unique cell structure that allows it to retain the historical information from prior inputs. Therefore when properly trained, LSTMs can predict future values by using relationships to previous data.

An LSTM cell consists of four major components: cell state (c_t), forget gate, input gate, and output gate. The cell state performs the LSTM memory function by storing the information received in the previous time-steps. Cell state is controlled using gates that allow information to be deleted or updated. The forget gate determines how much of the information stored in the cell state will be forgotten, while the input gate determines how much of the current input will be added to the cell state. The output gate, the last component of the LSTM cell, decides what information will be used as output (h_t) in the current time-step, taking the cell state and the current input into consideration. The inputs (x_t) and outputs (o_t) of an LSTM cell can be seen in Figure 1.

For the LSTM cell the outputs c_t and h_t, necessary input and forget gate equations are given in Equations 1 and 2. The mathematical expression for the cell state (c_t) is given in Equations 4 and 5 and the output gate result is obtained from Equation 3. And the hidden state of the cell is calculated using Equation 6.

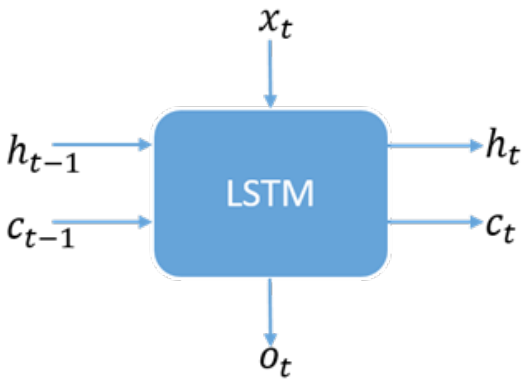

Figure 1. Inputs and outputs of an LSTM unit.

$$i_t = \sigma(W_i x_t + U_i h_{t-1} + b_i) \quad (1)$$

$$f_t = \sigma(W_f x_t + U_f h_{t-1} + b_f) \quad (2)$$

$$o_t = \sigma(W_o x_t + U_o h_{t-1} + b_o) \quad (3)$$

$$\tilde{c}_t = tan(W_c x_t + U_c h_{t-1} + b_c) \quad (4)$$

$$c_t = f_t \odot c_{t-1} + i_t \odot \tilde{c}_{t-1} \quad (5)$$

$$h_t = o_t \odot \tan(c_t) \quad (6)$$

2.1.2. Gated Recurrent Unit

Gated Recurrent Unit (GRU) is a recurrent neural network architecture used for processing sequential data and, similar to other recurrent neural network architectures such as LSTM, is capable of maintaining information from previous time-steps (Cho et. al, 2014). GRU is frequently used in time series prediction and sequential data processing such as natural language processing problems.

Compared to LSTMs, GRU architecture has a simpler design and unlike LSTM, which has a separate cell state and output gate, GRU has three key elements: an update gate, memory (h_t), and a reset gate. These elements control how the cell's information is updated. The update gate determines how much of the previous information is updated and preserved. The reset gate controls how much past information is removed in the current step. Memory contains the information that has been updated using previously passed and current data, controlled by the update and reset gates. The inputs (x_t) and outputs (o_t) of a GRU cell is shown in Figure 2. The expressions for the reset and update gates used to calculate the cell output, h_t is obtained by using Equations 7 and 8, respectively and the cell output is calculated using Equations 9-10

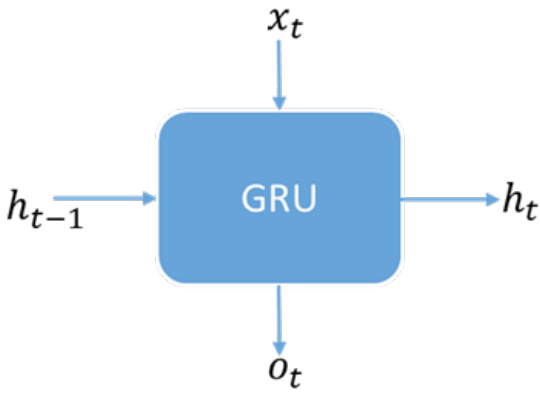

Figure 2. Inputs and outputs of a GRU unit.

$$z_t = \sigma(W_z x_t + U_z h_{t-1} + b_z) \quad (7)$$

$$r_t = \sigma(W_r x_t + U_r h_{t-1} + b_r) \quad (8)$$

$$\tilde{c}_t = tan(W_h x_t + U_h(r_t \odot h_{t-1}) + b_h) \quad (9)$$

$$h = z_t \odot h_{t-1} + (1 - z_t) \odot \tilde{h}_t \quad (10)$$

2.1.3. Temporal Convolutional Network

Temporal Convolutional Network (TCN) is a deep neural network architecture that is designed primarily for modeling and prediction of sequential data. TCNs are convolutional neural networks (CNNs) that have been evolved to adapt CNN's pattern recognition abilities for time series analysis (Bai et. al, 2018). The main component of TCN is dilated convolutional layers that capture long-term connections. In addition to these a dilated convolution layers, TCN architecture also has a residual block with normalization, activation, and dropout layers as seen in Figure 3.

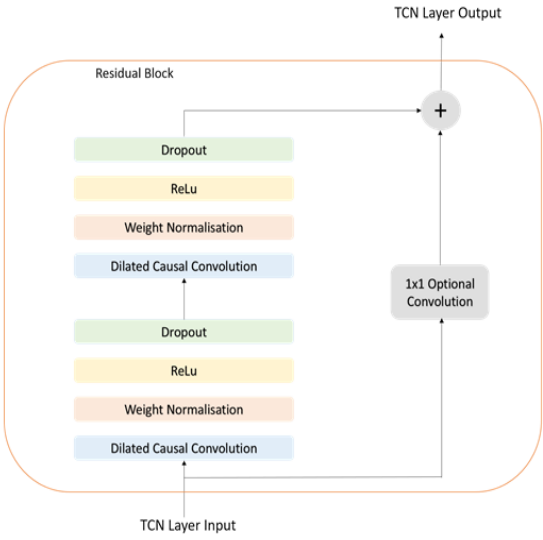

Figure 3. Inputs and outputs of Temporal Convolutional Network.

2.1.4. Temporal Convolutional Network with Leaky ReLU

In this study, in addition to the three DNN architectures, Temporal Convolutional Network that uses Leaky ReLU activation function (TCN-

LR) model is also trained and tested on the sensor data. In this modified TCN architecture the rectified linear unit (ReLU) function in the activation layer of the TCN architecture seen in Figure 3 has been changed and replaced with the leaky rectified linear unit (Leaky ReLU) function. This method shown promising results in previous prediction studies for different sensor data compared to the classical TCN models (Dudukcu et. al, 2022).

2.1.5. Ensemble Learning Method

Ensemble learning is a machine learning technique that is used to improve the performance of the results that may be obtained with a single method by combining multiple learning methods. Using multiple models to correct any potential errors can be achieved by various techniques including majority voting or weighted (Sagi and Rokach, 2018).

In this study, LSTM, GRU, TCN and TCN-LR models were trained separately for five different flight data, then ensemble model predictions were made using these DNN models. Ensemble learning method was carried out by averaging prediction probabilities of the four DNN methods. CNN method was not used within the EL-HAR architecture, the prediction since its recognition accuracy was low compared to other models.

2.2. Evaluation Metrics

Deep learning models are used to solve classification or regression problems. The performance of the models in solving these problems is determined by statistical processes called evaluation metrics. Evaluation metrics used in classification and regression problems may differ. The explanations and equations related to the evaluation metrics to be used in this study are given below.

2.2.1. Root Mean Square Error (RMSE)

The performance of prediction models are often assessed using the evaluation metric known as Root Mean Square Error (RMSE). RMSE is calculated using the square root of the mean of the squares of the difference between the predicted values and the actual values as shown in Equation 11. Smaller RMSE values suggest a better prediction performance for the models.

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(predicted_i - measured_i)^2} \tag{11}$$

2.2.2. Mean Absolute Error (MAE)

The Mean Absolute Error (MAE), another error measure used to assess the accuracy of prediction models, calculates the average of the absolute differences between the predicted values and the actual values (Equation 12). Smaller MAE values, similar to RMSE, signify a better performance for the prediction model.

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|predicted_i - measured_i| \tag{12}$$

2.2.3. Coefficient of Determination (R^2)

Another statistical metric, the coefficient of determination, often known as R-squared or R^2, is also used to assess how well a regression model fits the data and how accurate the prediction model is. The R^2 value can be calculated using Equation 13. This metric can range from 0 to 1, and the better the model fits the data, the closer the R^2 value is to 1.

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(predicted_i - measured_i)^2}{\sum_{i=1}^{N}(predicted_i - \frac{1}{N}\sum_{i=1}^{N} predicted_i)^2} \tag{13}$$

3. Simulation Setup

Within the scope of the study, time series prediction was performed with different deep learning models by using Commercial Aircraft Acceleration Sensor Data. For this purpose, first of all, body longitudinal acceleration (BLAC) sensor data in the data set was obtained and rearranged for the training process. After then, a training process of five different models created using three different deep learning architectures was carried out using these data. With the test processes performed at the end of the training process, it was examined which model showed the highest performance in time series prediction. Detailed information about the dataset is given in the first subsection of this section, then the test results and the evaluation metrics values used to interpret the test results are given in the "Simulation Results" subsection.

3.1. Dataset

Commercial flight data published by NASA for FOQA were used in the study (https://c3.ndc.nasa.gov/dashlink/projects/85/). Sensor data prediction was performed with BLAC sensor data of five different flights taken from these data and the performance of five different DNN methods was compared. The sensor data sample sizes of five different flights selected to be used in the study is shown in detail in Table 1.

Table 1. Dataset flight sample sizes.

	Data Samples
Flight 1	54976
Flight 2	194752
Flight 3	206144
Flight 4	195136
Flight 5	180864

3.2. Simulation Results

First, trainings for the LSTM, GRU, TCN, and TCN-LR models were conducted for the study. For this purpose, a different model was trained for each flight and the flight data were separated as 70% and 30% for training and test sets respectively for every flight. The history window size for the models was selected as 10, and the trainings were done accordingly. For the DNN architectures 256 units were used and the training was carried out for 200 epochs with 1024 batch sizes. The optimizer for all models were chosen as Adam and trainings were carried out using the mean squared error loss function.

The performance of both the four DNN methods and the method created using ensemble learning were tested, after the training was completed. The prediction performances of the DNN methods were examined using RMSE, MAE and R^2 and the results obtained for each flight are given in Figure 4, Figure 5 and Figure 6, respectively. In addition to these results, the average performance of each method for different metrics are also shown in Figure 7, Figure 8 and Figure 9 for comparison of the methods.

Figure 4. RMSE results for five different flight sensor data.

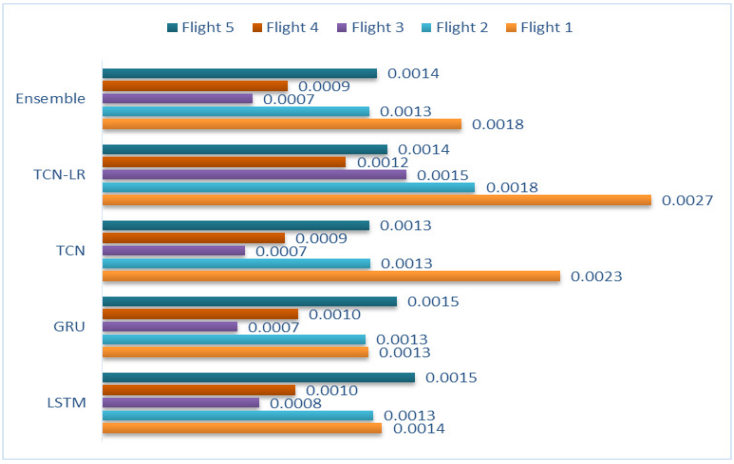

Figure 5. MAE results for five different flight sensor data.

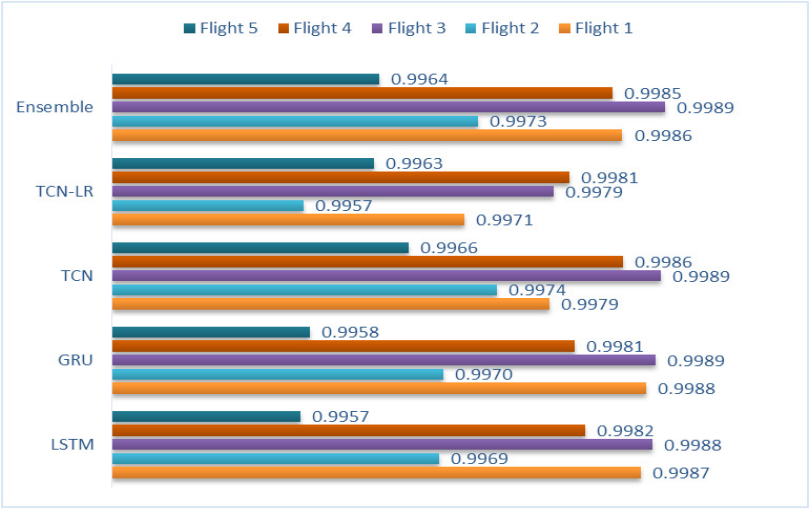

Figure 6. R^2 results for five different flight sensor data.

Figure 7. Average RMSE values for five deep learning methods on the test data.

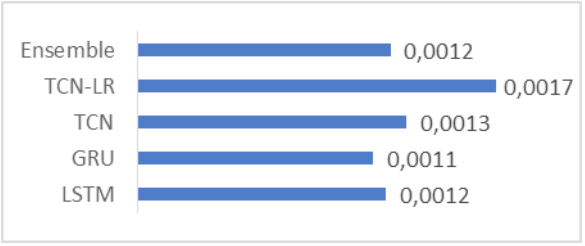

Figure 8. Average MAE values for five deep learning methods on the test data.

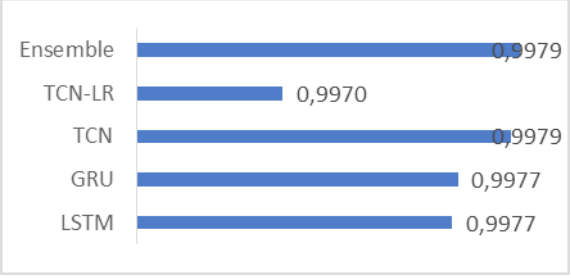

Figure 9. Average R^2 values for five deep learning methods on the test data.

When the performance results of the five DNN methods are examined, it is seen that the Ensemble Learning Method gives the best average RMSE performance value of 0.0021, and the highest average R^2 value of 0.9979. When the flight RMSE values are examined, it is seen that the lowest RMSE value, 0.0014, can also be obtained with the Ensemble Learning Method for Flight 3. Similarly, the highest R^2 value was obtained as 0.9989 using the Ensemble Learning Method for Flight 3.

4. Conclusion

In this benchmarking study, time series prediction was performed with five different DNN methods using commercial aircraft acceleration sensor data. In the study, the sensor data prediction performances of LSTM, GRU, TCN, TCN-LR and Ensemble Learning Methods were compared. When the test results obtained were examined, it was seen that the lowest RMSE and highest R^2 scores were obtained by using the Ensemble Learning method.

With the results obtained in this study, for the acceleration data of aircrafts, the DNN methods that can be used were compared and it was seen that most successful prediction results can be obtained by using ensemble learning. Furthermore, in future studies, anomaly prediction and flight status control can be made on the flight acceleration data using these methods.

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CHAPTER 3

THE EFFECT OF EARTHQUAKES ON FLOODS

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1. INTRODUCTION

1.1. Floods

Approximately 10% of the world's population is reported to live in coastal areas, and these areas are typically characterized by densely populated cities in terms of population density (McGranahan et al., 2007). Cities constructed in coastal areas and near rivers can occasionally be exposed to terrestrial hazards such as rising sea levels, floods, tsunamis, and storm surges caused by both natural and anthropogenic processes (Syvitski et al., 2009; Nicholls and Cazenave, 2010). The rising sea and river levels can result in significant loss of life and material damage in cities established in coastal areas and near rivers (Nicholls and Cazenave, 2010; Hallegatte et al., 2013).

Floods can be defined as the result of increased water input due to factors such as excessive rainfall, snowmelt, glacier breakage, ice accumulation, rising lake/sea levels, and the destruction of bridges/dams, causing the water to exceed the banks of river channels and submerge the surrounding areas that are normally not covered with water (Terzioğlu, 2018; Kron et al., 2019). Floods can be triggered by natural phenomena, including river floods, tides, coastal storms, and intensified rainfall in urban areas, resulting in the breaching or overflow of river embankments. Additionally, floods can occur due to anthropic events such as the uncontrolled release of water, hydraulic structure malfunctions, and dam collapse (Maranzoni et al., 2023).

Floods are natural disasters that cause the highest loss of life and property worldwide after earthquakes. Floods are responsible for 43% of natural disasters globally and 47% of weather-related natural disasters. It is reported that between 1995 and 2015, floods adversely affected 2.3 million people and caused approximately $662 billion in damages. However, it is also emphasized that the number of people living in flood-prone areas in the world is approximately 800 million, and about 70 million of these people are exposed to floods every year (UNISDR, 2015). Furthermore, floods occurring in impermeable and highly inclined terrains not only result in loss of life but also cause significant damage to lands, agricultural crops, roads, railways, buildings, possessions, and company stocks (Elbaşı, 2022).

Floods can have destructive, intense, and deadly effects by carrying large volumes of water in international rivers for weeks or months, while also occurring in urban basins with relatively less impact but over a shorter period of hours (Kron et al., 2019; Kundzewicz et al., 2019). Floods are classified as natural disasters, and they are influenced by various fac-

tors including geology, climate, geomorphology, hydrography, population density, settlement characteristics, soil/vegetation cover of the basin, land use, and economic activities (Ahmad and Afzal, 2020; Uysal and Sunkar, 2022).

Flood risk is reported to depend on flood exposure, flood hazard and flood vulnerability, driven by the complex interplay of terrestrial and hydrological, climate and socio-economic systems (Kundzewicz et al., 2019). The factors influencing flood risk are shown in Figure 1.

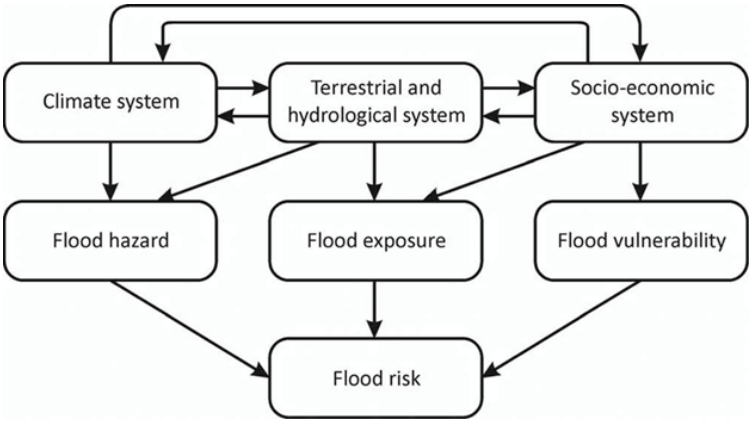


Figure 1. *Factors influencing flood risk (Kundzewicz et al., 2018)*

1.2. Earthquakes

Earthquakes, which occur as a result of crustal movements, can be classified into three different groups based on their formation types: subsidence earthquakes, tectonic earthquakes, and volcanic earthquakes. Collapse earthquakes occur in rocky regions as a result of the gradual thinning and collapse of underground cavities over time. Collapse earthquakes can cause significant loss of life and property damage in populated areas. Volcanic earthquakes occur as a precursor to volcanic activity when volcanoes become ready for eruption. Tectonic earthquakes occur in the moving parts of the earth's crust due to the release of kinetic energy as a result of various stresses in the earth's crust or the start of the deterioration of the underground balances due to different reasons. Stable and geologically mature regions, known as the older parts of the Earth, such as central Africa, northern Asia, northern Europe, Australia, and north-eastern North America, are characterized by infrequent seismic activity and low levels of earthquake damage. However, dynamic and young parts of the world, such as Anatolia, Iran, southern Europe, the Japanese islands, coastal regions of

the Pacific Ocean, the Himalayas, and surrounding areas, are places where earthquakes are more frequent and where earthquakes losses are significant (Figure 2) (Sür, 1993; Bernal and Cardona, 2018). Earthquakes significantly impact surface and subsurface hydrological regimes at various temporal and spatial scales, giving rise to issues such as earthquake-generated water waves, tsunamis, landslides, floods, and soil liquefaction. Additionally, they bring about problems including surface uplift, subsidence, alterations in river profiles, changes in the flow and volumes of surface and/or groundwater, as well as deformation and fracturing of underground infrastructure. Furthermore, the location, timing, magnitude, and depth of earthquakes have both natural and anthropic influences on hydrological regimes (Quigley and Duffy, 2020; Cavalieri et al., 2023).

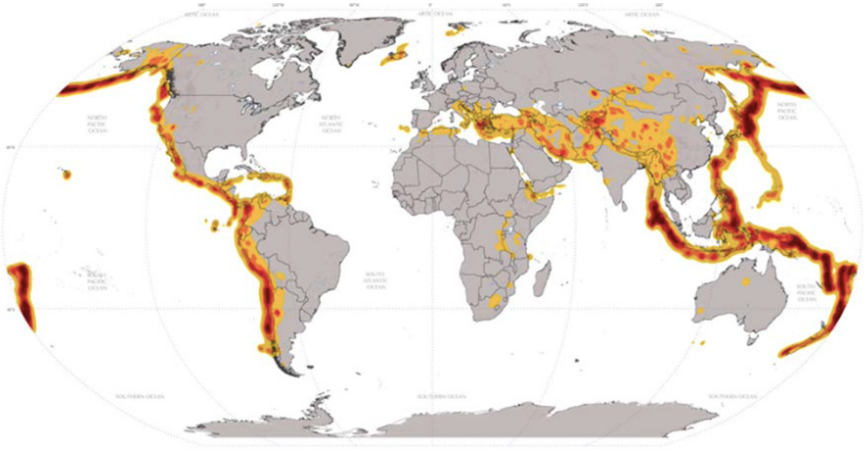


Figure 2. *Seismic hazard map (Bernal and Cardona, 2018)*

Disasters are defined as all events occurring in residential areas that are caused by natural, human, and technological hydrological, geological, and meteorological changes, resulting in environmental, economic, and social losses, as well as interrupting or completely stopping normal life and human activities, thereby affecting society. Located in the Alpine orogenic mountain belt and exposed to various natural disasters over the years due to its topography, geological structure, meteorological characteristics, and tectonic formation, Türkiye has suffered significant loss of life and property damage as a result of recurrent natural disasters such as earthquakes, floods, landslides and avalanches that occur at regular intervals (Ergünay, 2007). Precautions and planning measures to be taken for earthquakes, which cannot be known in advance with today's technologies, come to the fore as an important factor in minimizing life and material losses. For this

purpose, synthetic earthquake scenarios can be prepared and a prediction can be made for the intensity of possible large earthquakes, the losses in the regions to be affected by possible earthquakes, and the measures that can be taken (Üsküplü, 2012).

In Türkiye, which is located on active earthquake belts, primarily the North Anatolian Fault Zone (NAFZ) and the East Anatolian Fault Zone (EAFZ), about 66% of the total land area and about 71% of the population are within the first and second-degree earthquake zones (Türkoğlu, 2001; Sönmez, 2011). The NAFZ is defined as a right-lateral strike-slip fault zone that extends from Lake Van to the Saros Gulf. The EAFZ is defined as a northeast-southwest trending left-lateral strike-slip fault zone that joins with the NAFZ in Karlıova and extends to the Amanos Mountains (Ketin, 1969; Üsküplü, 2012). As shown in Figure 3, NAFZ exhibits high seismic activity due to the southward movement of the Arabian plate towards the Eurasian plate located in the north. As a result of the north-south compression of the Anatolian block, the Anatolian plate moves westward by about 20 mm along the left-lateral strike-slip EAFZ and right-lateral strike-slip NAFZ (Kıyak et al., 2023).

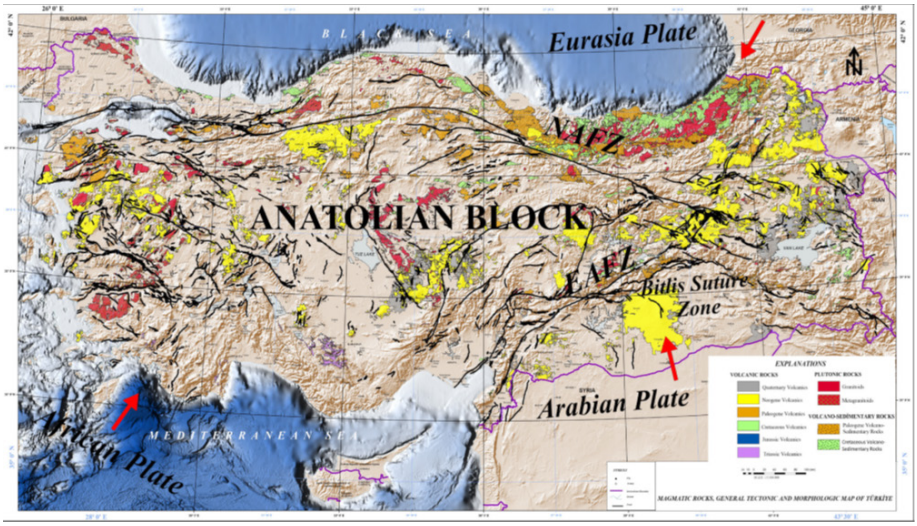


Figure 3: *NAFZ, EAFZ, and plate movements (Kıyak et al., 2023)*

2. THE EFFECTS OF EARTHQUAKES ON FLOODS

The effects of earthquakes are classified into primary effects and secondary effects, where primary effects are defined as the direct impacts of the earthquake, and secondary effects are triggered by the primary effects (Tatevossian et al., 2009). The primary effects of an earthquake manifest on the Earth's surface and include surface uplift, subsidence, or other activities observed due to tectonic deformation caused by the earthquake. In secondary effects, they are induced due to ground shaking, and events such as floods, tsunamis, liquefaction, landslides, shifting rocks, or ground fissures are observed (Choudhury et al., 2016). Recently, disasters such as earthquakes and floods have been occurring frequently worldwide, causing more casualties and economic damages compared to other disasters. When examining the disasters that occurred in the past, it is evident that numerous floods occurred before or after earthquakes. To provide specific examples, following the 8.0 magnitude earthquake in Sichuan province, China, in May 2008, a significant flood occurred in the same province in September 2008, causing damage to thousands of houses. In April 2013, following another earthquake in Sichuan province (magnitude 7.0), a large-scale flooding event was observed in the same year in July. Following the Darfield earthquake in 2010, floods occurred in rural areas near the Greendale fault and other surrounding rural areas. After the 9.0 magnitude earthquake in the Tohoku region of Japan in 2011, flooding occurred in residential areas due to the Fujinuma Reservoir (Quigley and Duffy, 2020; Dong et al., 2022). Figure 4 illustrates some flood images observed after earthquakes.

Figure 4: *Some flood images observed after earthquakes (Quigley and Duffy, 2020)*

When similar earthquake and flood events are examined, it is observed that these two natural disasters have a combined effect, which is attributed to structural performance. It is reported that earthquakes primarily have an impact on structural performance. In this case, it is stated that flood scouring has a relatively lower level of impact when the damage is mild to moderate, while it has a more significant level of impact when the damage is severe. However, when the combined effect of earthquakes as well as flood carving and earthquakes on the risk of migration is compared;

It is added that the combined effect significantly affects the risk of migration and increases the risk of migration. Therefore, it is emphasized that the significant impact of flood scouring on the seismic performance of structures should not be overlooked in terms of loss of life and property damage (Dong et al., 2022). In this context, recent studies have focused on assessing the risks posed by the combined effects of earthquakes and floods on structures and evaluating the resilience capacities of buildings. In a study, it was reported that liquefaction decreased in the earthquake and flood-prone areas due to the increase in floodwater levels (Tyagunov et al., 2018). Ganesh Prasad and Banerjee (2013) reported that in bridges exposed to flooding, the seismic vulnerability of bridges increases nonlinearly with an increase in scour depth. The events occurring in surface and subsurface hydrology following earthquakes are presented in Table 1, while the visual representation of the scenario of fault-induced river channel breaks in a meandering river system and the impact of the Fault scarp barrier on river flow behavior is provided in Figure 5.

Table 1. *The events occurring in surface and subsurface hydrology following earthquakes (Quigley and Duffy, 2020)*

Category	Effect
Landslide Dam	Earthquakes can trigger landslides that cause changes in the volume, distribution, and flow of surface waters in a basin. As a result of this event, one or two large dams and several small dams can be formed.
Liquefaction	Lateral spreading and ground settlement resulting from liquefaction lead to disruptions in horizontal infrastructure. Additionally, liquefied gravity flows can cause mass losses on land and can also contribute to the formation of tsunamis.
Seiche	Oscillations can occur at distances far beyond the epicenter of an earthquake. These oscillations, which have numerous examples worldwide, can result in building damage, changes in river levels, or landslides.
Tsunami	Tsunami-induced flooding can occur as a result of submarine landslides or fault ruptures in offshore areas. Low-magnitude earthquakes in faults with low rigidity can lead to large tsunamis.
Surface-water changes	Changes in river discharge occur as a result of continuous variations, the release of groundwater, and changes in gradient. This event can occur weeks or months after an earthquake.

Groundwater changes	The responses of groundwater have been observed following earthquakes in countries such as the United States of America, Indonesia, Japan, China, and New Zealand. Well levels can exhibit responses up to thousands of kilometers, while the pressure and temperature of spring discharge can respond within hundreds of kilometers. The scale of the well response is also related to the magnitude of the earthquake.

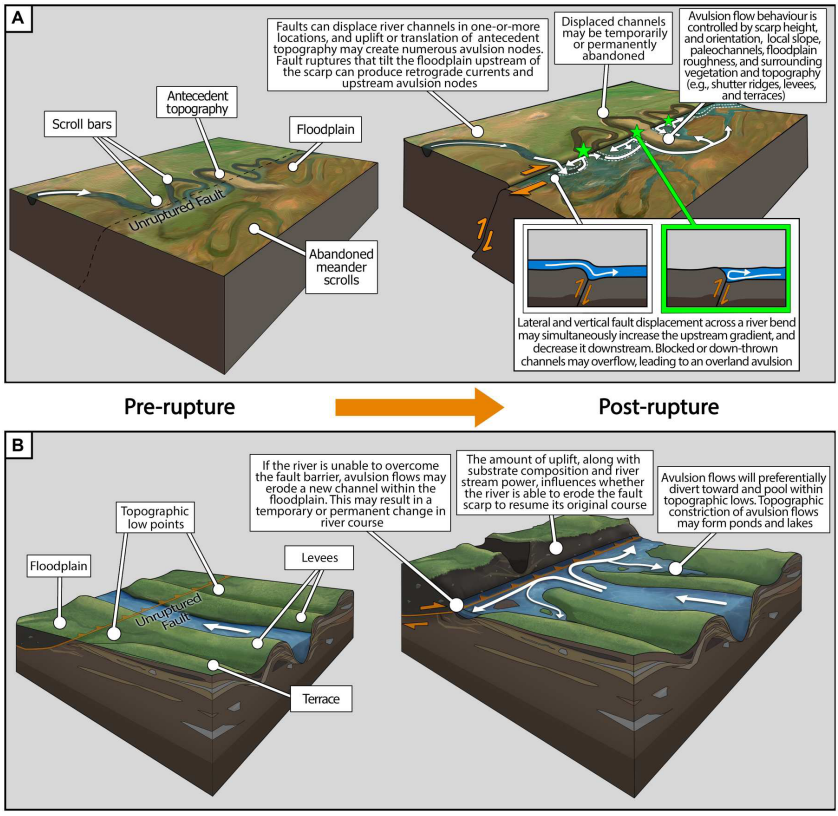


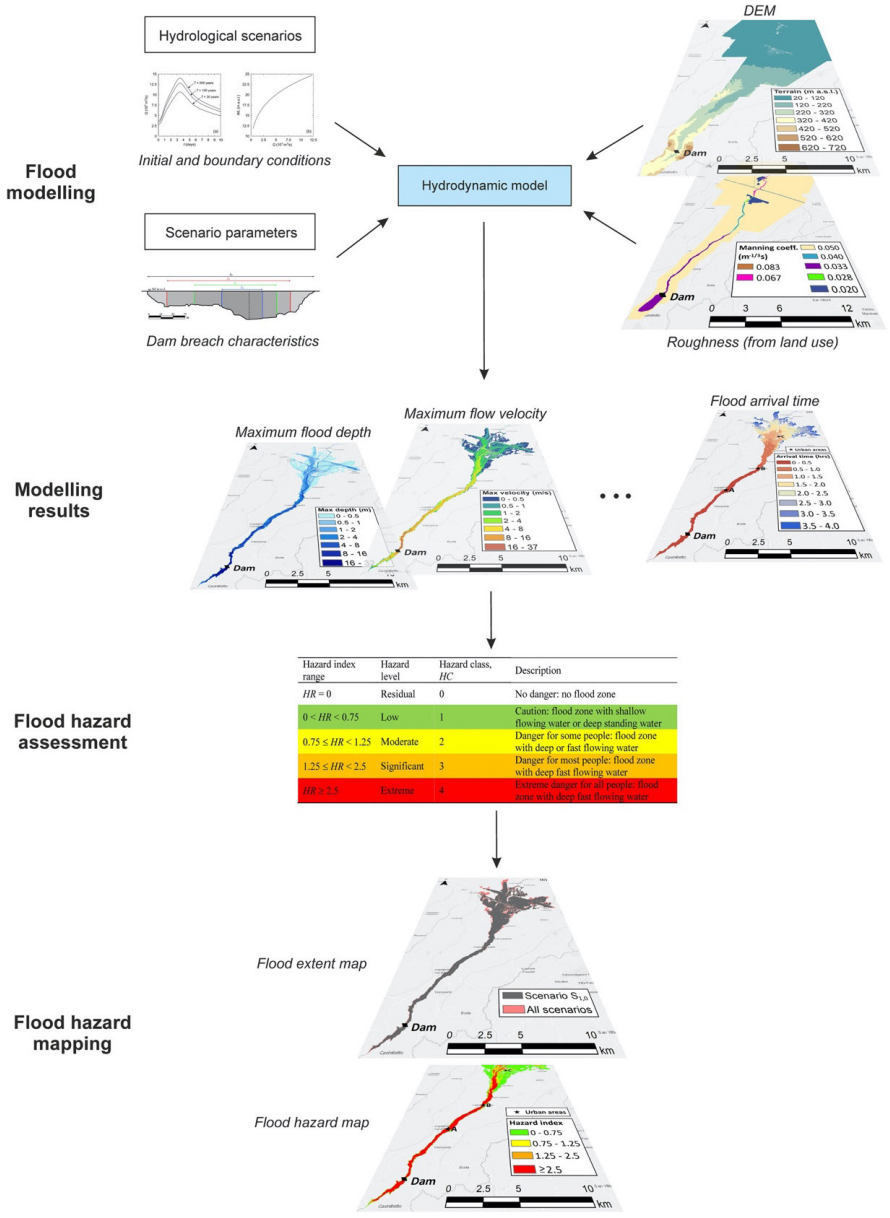
Figure 5. A: *The visual of river channel disruptions caused by faulting in meandering river systems.* **B:** *The effect of fault scarp barriers on river flow behavior (McEwan et al., 2023)*

3. REDUCING FLOOD RISKS: STRUCTURAL MEASURES AND VARIOUS STRATEGIES

Floods pose a risk when they have the potential to cause damage to both environmental and anthropic systems, and flood risk is defined by the EU Flood Directive (Council of Europe, 2007) as "the entirety of potential adverse consequences on human health, environmental activities, and economic activities associated with a flood probability." Flood risk comprises three components: "flood hazard," which characterizes the frequency and intensity of floods, "exposure," which refers to the people, infrastructure, buildings, social activities, and economic activities affected by floods, and "vulnerability," which denotes the tendency of individuals outside the flood to suffer harm from it (Kron, 2002; IPCC, 2012; Maranzoni et al., 2023). Thus, as a result through the effective evaluation of flood risk analysis outcomes, raising public awareness about potential damages will help minimize loss of life, economic damages, social impacts, and losses in cultural/environmental heritage, thereby preventing significant losses (De Ruiter et al., 2017; Ahmad and Afzal, 2019; Maranzoni et al., 2023).

One of the most effective measures to be taken against floods is the creation of flood hazard maps. Through the use of flood hazard maps, risk maps can be generated, enabling the implementation of protection measures against floods based on the level of risk. Flood risk maps provide various contributions such as spatial distribution of flood risk in terms of potential outcomes and damages, emergency response planning, reduction of existing risks, prediction of new emerging risks, and raising public awareness about floods. The creation of flood hazard maps primarily requires a well-established network of streamflow observation stations spanning several years (De Moel et al., 2009; Elbaşı, 2022; Maranzoni et al., 2023).

Flood models are utilized to forecast flood-prone areas and generate flood hazard maps. Flood frequency analysis is utilized in running flood models. In flood frequency analysis, which is categorized into point and regional analyses, point flood frequency analysis is conducted using data from streamflow observation stations and is considered a simple and easily applicable method (De Almeida et al., 2018; Elbaşı, 2022). In point flood frequency analysis, the analysis is focused on a single station/point, whereas in regional flood frequency analysis, data from multiple stations within a particular region are scanned. In regional flood frequency analysis, three distinct steps are followed: identifying homogeneous regions, determining regional distribution models, and developing regional relationships based on the distribution outcome (Elbaşı, 2022). Figure 6 illustrates the assessment of flood hazards using a quantitative method.



Hazard index range	Hazard level	Hazard class, *HC*	Description
$HR = 0$	Residual	0	No danger: no flood zone
$0 < HR < 0.75$	Low	1	Caution: flood zone with shallow flowing water or deep standing water
$0.75 \leq HR < 1.25$	Moderate	2	Danger for some people: flood zone with deep or fast flowing water
$1.25 \leq HR < 2.5$	Significant	3	Danger for most people: flood zone with deep fast flowing water
$HR \geq 2.5$	Extreme	4	Extreme danger for all people: flood zone with deep fast flowing water

Figure 6. *Assessment of flood hazard using a quantitative method (Maranzoni et al., 2023)*

CONCLUSION

A significant portion of the world's population resides in coastal areas and along riverbanks, where they are vulnerable to disasters such as floods, resulting in numerous casualties and property losses due to natural and anthropic processes. Floods, which are defined as the inundation of surrounding areas due to the inability of river channels to convey the increased water inflow caused by reasons such as excessive rainfall, snowmelt, glacier break-up, ice accumulation, rising lake/sea levels, and bridge/dam failure in non-water-covered basins under normal conditions, can occur as a result of natural events as well as anthropic events such as the uncontrolled release of water due to accidents, malfunctioning of hydraulic structures, and an anthropogenic dam collapse. Earthquakes are briefly defined as movements of the Earth's crust and are categorized into three classes based on their formation mechanisms: subsidence, tectonic, and volcanic. In regions composed of rocks, subsidence earthquakes occur as a result of the gradual collapse of underground cavities. Earthquakes that result from volcanic activity are referred to as volcanic earthquakes. Tectonic earthquakes, on the other hand, occur when the balance underground is disrupted due to various stresses in the Earth's crust. When the earthquakes that have occurred around the world throughout history are examined; while earthquakes are less common in central Africa, North Asia, northern Europe, Australia, and northeastern North America, earthquakes occur more frequently in regions such as Anatolia, Iran, southern Europe, the Japanese islands, the border regions of the Pacific Ocean, the Himalayas, and their surroundings. In retrospect, many floods occurred before or after earthquakes. By preparing synthetic earthquake scenarios against earthquakes, an estimate can be made for the intensity of possible earthquakes, possible losses, and measures that can be taken. Various measures can be taken to address floods by creating flood hazard maps and risk maps, allowing for the assessment of flood risk distribution, planning emergency response measures, reducing existing risks, and predicting potential new risks. It has been concluded that in regions worldwide where various natural disasters occur at certain intervals, in addition to designing structures based on risk maps, there is a need for increased public awareness regarding floods and earthquakes, as well as improving educational levels in schools.

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CHAPTER 4

PROBLEMS CAUSED BY ANTIBIOTIC RESIDUES IN MILK AND DAIRY PRODUCTS

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INTRODUCTION

Milk and dairy products are recognized as important sources of animal protein that contribute significantly to human growth and development (Dikko et al., 2010). Milk can be consumed directly as drinking milk as a result of different heat treatments, or it can be used by processing into various products (such as butter, cheese, kefir, yogurt, and ice cream) (Adetunji, 2008). However, due to industrial and/or agricultural wastes, various chemical substances that can negatively affect human health may be found in milk available on the market (Girma, 2014). These chemical substances are defined as antibiotics, pesticides, mycotoxins, heavy metals, and dioxins (Khaniki, 2007).

Antibiotics are defined as antimicrobial substances that inhibit the growth and development of various microorganisms. Currently, antibiotics are widely used worldwide to treat animal diseases, promote animal weight gain and increase production efficiency (Berghich et al., 2021; Georgakakos et al., 2021). It is reported that approximately 12,000 tons of antibiotics are used annually in the livestock industry worldwide, of which approximately 9,000 tons are used to treat infectious diseases (Moghadam et al., 2016). Beta-lactams, aminoglycosides, tetracyclines, sulfonamides, macrolides, and quinolones are among the antibiotic groups used especially in the treatment of mastitis, respiratory tract infections, and digestive system infections in dairy animals and in the treatment of infectious diseases in farm animals. Antibiotics are applied as an infusion into the udder during the treatment of mastitis, which is common in dairy cattle (Mahmoudi et al., 2013; Khanal et al., 2018; Chiesa et al., 2021).

After antibiotics are given to animals, a certain amount of time must pass for the drug to be eliminated from the body. Meat, eggs, and milk should not be consumed in accordance with the instructions until this period is completed (Moudgil et al., 2019). In general, most of the major compounds of antibiotics and their metabolites are excreted in the urine, with a lesser degree of excretion in the feces. However, after excretion, a portion of the drugs can remain as residues in milk, eggs, and meat for a certain period of time (Sachi et al., 2019). Antibiotic residues are defined as the chemicals or metabolites of pharmaceutical products that may accumulate in the tissues or oral cavities of animals treated with antibiotics. The presence of antibiotic residues in milk is associated with the overuse of antibiotics. Several types of antibiotics can be found in milk, depending on the amount used, and these antibiotics can have harmful effects on human health (Zheng et al., 2019). In terms of human health and safety, maximum residue limits (MRLs) have been determined for different classes of antibiotics in food, generally ranging from 4 to 1500 μg/kg (Gaudin, 2017). Although these limits help to protect the rights of consumers, there

is no guarantee that foods containing residues above this limit cannot be consumed in regions where marketing processes are very intense (Treiber and Beranek-Knauer, 2021).

The presence of antibiotics in the food and agricultural sector can lead to significant financial consequences due to raw material losses by delaying or completely inhibiting the necessary fermentation processes in cheese and yogurt production (Bakırcı and Akyüz, 1996; Gajda et al., 2018). Factors that can cause antibiotic residues in milk and dairy products include the accumulation of high levels of antibiotics in tissues due to incorrect dosage or excessive use of antibiotics used in the treatment of infectious diseases such as mastitis (Chiesa et al., 2021), improper disposal of antibiotic containers used for animal treatment (Singh et al., 2014), deliberate addition of antibiotics to milk to delay spoilage (Mottaghiyanpour et al., 2018), improper milking practices and inadequate cleanliness of the milking facility (Vishnuraj et al., 2016), failure to identify treated cows (Singh et al., 2014), and lack of knowledge among farmers regarding the impact of antibiotic residues on human health (Beyene, 2016).

Continuous exposure of certain microorganisms to antibiotics can lead to a decrease in the effectiveness of the antibiotic due to changes that occur in the microorganism. Bacteria are known as organisms with extraordinary genetic flexibility, allowing them to respond to any environmental threat. Bacteria can acquire resistance to antibiotics either by changing their DNA during cell replication, called as mutation, or by acquiring the organism's genes and incorporating them into their own genetic material (Bakırcı and Akyüz, 1996; Munita and Arias, 2016). Bacteria with plasmid DNA play an important role in the spread of antibiotic-resistant genes (Avşar and Berber, 2014).

EFFECTS OF ANTIBIOTIC RESIDUES IN MILK AND DAIRY PRODUCTS

Antibiotic Residues in Milk and Milk Powder

The presence of antibiotics in milk has a significant impact on the food industry, as various bacteria used in the fermentation process can be inhibited due to their sensitivity to antibiotics (Bakırcı and Akyüz, 1996). This can result in the loss of organoleptic properties of final products and lead to failed coagulation or maturation in dairy products (Berruga et al., 2007). Antibiotics such as tetracyclines, sulfonamides, and aminoglycosides are mainly applied to animals that have recently given birth, resulting in antibiotic residues in milk. However, off-label use of antibiotics and mainly dosages deviating from the recommendations of drug manufacturers, are among the reasons for the formation of antibiotic residues in milk.

Other reasons for the formation of residues in milk are improper milking practices and inadequate cleanliness of the milking equipment (Gaurav et al., 2014; Vishnuraj et al., 2016). In general, it is reported that in order to prevent antibiotic residues in milk, it is necessary to determine an effective detection method and to establish regular basic monitoring and surveillance policies throughout the country (Gaurav et al., 2014; Vishnuraj et al., 2016). In addition, it is emphasized that it is important to increase the education level of the producers about the use of antibiotics and to pay attention to the cleaning conditions (Sachi et al., 2019).

Recently, the presence of antibiotics in milk and dairy products and the contamination of food with chemical residues have emerged as a public health problem. Since these chemical residues are resistant to pasteurization processes (72°C for milk), the elimination of drugs cannot be performed (Tian et al., 2017; Gbylik-Sikorska et al., 2021). Noori et al. (2013) determined that milk powders available for sale in Iran contained 30% beta-lactam and 17.5% tetracycline, respectively. In their study, they expressed that the thermal processes applied during the production of milk powders were inefficient in eliminating antibiotics, posing a significant risk for children who are consistently fed with milk powder. In heat-treated milk samples, it was reported that only 1% of beta-lactam antibiotics were degraded at the pasteurization temperature of 72°C for 15 min and that beta-lactam antibiotics, including cefoperazone and cefuroxime, were degraded after 20 min at 120°C (Roca et al., 2011). In a study conducted by Gaurav (2015), it was found that 13.5% of the 133 milk samples collected from certain regions in India tested positive for tetracyclines, 10% for fluoroquinolones, 6.67% for aminoglycosides, and 4.16% for sulfamethazine. Bahramian et al. (2022) investigated antibiotic residues in raw and pasteurized milk samples in their study and found the presence of antibiotic residues to be 26% and 21%, respectively. They reported that raw milk samples were contaminated with antibiotic groups such as beta-lactams, tetracyclines, sulfonamides, fluoroquinolones, aminoglycosides (gentamicin), macrolides, flumequine, and amphenicols. Similarly, they indicated that pasteurized milk samples were contaminated with antibiotic groups including beta-lactams (penicillin), tetracyclines, sulfonamides, aminoglycosides (neomycin), flumequine, fluoroquinolones (enrofloxacin), florfenicol, and macrolides. Due to the heat applied during the pasteurization process, a portion of the water in the milk evaporates, leading to concentration, and consequently, the antibiotic residues also become concentrated in the heat-treated milk (Anika et al., 2019). Therefore, since antibiotic residues or their metabolites are more concentrated in heat-treated milk compared to raw milk, they can pose risks to human health and product safety. Meklati et al. (2022) investigated beta-lactams and tetracyclines in 445 milk samples, that 90.4% of the

samples were contaminated with these compounds, and 55.3% exceeded the Maximum Residue Limit (MRL) for contamination. Furthermore, they stated that beta-lactams, specifically cloxacillin (1231 µg/kg) and penicillin G (2062 µg/kg), were the most frequently detected antibiotic group as the main compounds and their metabolites.

Table 1. *Antibiotics detected in raw milk and pasteurized milk*

Types of antibiotics		Types of antibiotics	
In raw milk	Tetracycline (Bahmani et al., 2020)	**In pasteurized milk**	Penicillin, tetracycline (Bonyadian and Kordi, 2020)
	Gentamicin, tylosin, chloramphenicol, sulfonamides, penicillin (Nemati et al., 2020)		Flomocaine, sulfonamides and enrofloxacin group (Alimohammadi et al., 2020)
	Flomocaine, tetracycline, sulfonamide, and enrofloxacin groups (Alimohammadi et al., 2020)		Macrolides (Zarangush and Mahdavi, 2016)
	Beta-lactams (Mottaghiyanpour et al., 2018)		Florfenicol (Karami-Osboo et al., 2016)
	Macrolides, enrofloxacin group (Zarangush and Mahdav, 2016)		Oxytetracycline (Rasoli et al., 2014)
	Oxytetracycline (Asadpour, 2016)		Neomycin (Movassagh and Karamibonari, 2014)

Cheese

Depending on their physicochemical properties, as well as their ability to interact with fat and protein components, antibiotics can be found in greater or lesser amounts in milk curds (Giraldo et al., 2017; Shappell et al., 2017). According to the World Health Organization (WHO), fat-soluble antibiotics may pose a risk to consumers as they can reach higher levels in milk fat and cheese (WHO, 2007). The presence of antibiotic residues in milk intended for cheese production can lead to a decrease in the activity of the microorganisms used as starter cultures. This decrease in the activity creates a suitable environment for the growth of coliform bacteria, reducing the microbiological safety of the cheese (Thierry et al., 2017).

Starter cultures produce some of the enzymes responsible for the ripening of the cheese (McSweeney and Sousa, 2000). Beta-lactam that can be contaminated to milk changes taste and texture due to its effect on lipolytic bacteria in cheese (Berruga et al., 2016; Thierry et al., 2017). Furthermore, beta-lactam residues can delay the ripening of certain cheeses (Berruga et al., 2007). Additionally, antibiotic residues present in milk can also lead to undesired ripening in cheeses (Quintanilla et al., 2019).

Tona and Olusola (2014), in their study on the determination of tetracycline antibiotic residues in soft cheese samples, found that tetracycline ratios were significantly high (0.0080 ± 0.0034 ppm) in soft cheese samples. Lanyi et al. (2018) investigated the presence of antibiotic residues in homemade soft cheese production and the effect of applied heat treatment on these antibiotics. They observed high levels of tetracyclines and neomycins in milk samples used for cheese production and noted that these compounds transferred to the produced cheese and whey. Furthermore, they found that the heat treatment applied to the milk intended for cheese production did not completely reduce the amount of antibiotics. In a study on the effect of antibiotic residues in milk on cheese processing, Chiesa et al. (2020) added different concentrations (10 ppm, 20 ppm, and 40 ppm) of lincomycin to milk samples. Based on the results of acidity and microbiological analyses, they observed a continuous decrease in pH over time during a 12-hour acidification process in both unsupplemented samples and samples supplemented with different concentrations of lincomycin. Regarding the effect of lincomycin on cheese production, they observed a negative effect on lactic acid bacterial activity in all samples containing lincomycin (10 ppb, 20 ppb, and 40 ppb). Furthermore, they highlighted the negative role of lincomycin during the milk acidification process. The researchers emphasized that antimicrobial residues partially or completely inhibit the acid production of starter cultures, leading to potential technological and economic consequences in the dairy industry.

Due to the water-soluble nature of beta-lactams, they are mainly passed into the whey during cheese production (Giraldo et al., 2017). Therefore, low concentrations of antibiotics have been detected in commercial cheeses through antibiotic analysis (Gbylik-Sikorska et al., 2021). In addition to beta-lactams, tetracyclines are the most studied antibiotics in this regard and have been detected mostly in curd cheeses produced from cow, sheep, and goat milk (Gajda et al., 2018). Additionally, it was determined that the antibiotic residues decreased with the ripening process of the cheeses. In a study conducted by Quintanilla et al. (2019), it was noted that beta-lactam and erythromycin residues were not detected in Tronchon cheese after a 30-day ripening period.

Yogurt

Antibiotics reduce the development of lactic acid bacteria and even prevent fermentation by completely inhibiting over a certain concentration (Tabak, 2018). Novés et al. (2015) emphasized in their study that beta-lactam residues, which are close to or below the MRL level, can delay the coagulation of yogurt produced using sheep milk for more than 40 min. In a study on the antimicrobial susceptibility of starter cultures used in dairy products, it was revealed that antibiotics at the concentrations below the MRL reduced the activity of microorganisms such as lactobacilli and streptococci (Katla et al., 2001).

The greatest threat posed by antibiotic use is seen as the emergence and spread of antibiotic resistance (AR) in pathogenic bacteria. The frequent use of antimicrobial agents leads to the emergence of resistant bacteria (ARB) (EFSA, 2008). Therefore, the presence of antibiotic residues throughout the food chain can affect not only lactic acid bacteria but also pathogenic microorganisms, and lead to the development of antimicrobial resistance (AR) (Roca et al., 2015). Through the use of various starter cultures in the production of fermented dairy products, it is possible for a large number of these resistance genes to be transferred to the human body (EFSA, 2008). The transfer potential of antibiotic-resistance genes by probiotic bacteria has been identified as the major risk factor associated with their use (Çelik et al., 2016). It is generally believed that significant health problems can occur when beneficial probiotics carry infectious antibiotic-resistance genes and transfer them to saprophytic and/or pathogenic bacteria in the digestive system. Therefore, the development of methods that can reveal the presence of transferable (infectious) antibiotic-resistance genes in the evaluation of bacterial strains is emerging as an important criterion in terms of preserving human health (Hummel et al., 2007).

Han et al. (2015) determined that *Lactobacillus delbrueckii* subsp. *bulgaricus* strains isolated from commercial and homemade yogurts were 100% susceptible to vancomycin and erythromycin, while they showed 52.6% resistance to gentamicin. In their study, Çelik et al. (2016) examined the antibiotic resistance of lactic acid bacteria in 2 different homemade yogurts and 17 different brands of commercial yogurt obtained from the market. They determined the antibiotic resistance of the strains by measuring the zone diameter. According to the results of the study, 16 of the 19 isolated *Streptococcus* strains were found to be resistant to the antibiotic trimethoprim-sulphamethoxazole, while 3 strains showed moderate susceptibility to this antibiotic. When the *Lactobacillus* strains were evaluated, all strains were found to be resistant to the trimethoprim-sulphamethoxazole and ofloxacin antibiotics. Navrátilova et al. (2022) investigated the effects of cephalosporin antibiotics on the activities of yogurt cultures. They re-

ported that the ceftiofur antibiotic, which was among the cephalosporins tested, had a significant effect on especially the activity of yogurt cultures, as well as on pH, titratable acidity, and the contents of lactic, pyruvic, and acetic acids. They found that the ceftiofur antibiotic completely inhibited the metabolic activity of yogurt cultures even at the MRL concentration. Therefore, they reported that even very low concentrations of antibiotic residues in milk (e.g. 100 µg/kg MRL for ceftiofur) could significantly inhibit the growth and activity of yogurt cultures.

Ice Cream and Butter

Antibiotics can be contaminated to ice cream and butter either during the production process or after production due to various factors (Samaržija et al., 2012). Among these factors, besides raw milk used as raw material, water, fat, sugar, emulsifiers, flavoring agents, coloring agents, and thickeners can be a strong source of contamination (Mokbul et al., 2016). Therefore, ice cream and butter act as a good shelter for pathogenic and non-pathogenic microorganisms (Sohel et al., 2022).

Food and Drug Administration (FDA, 2016) has revealed that children consuming ice cream are susceptible to various foodborne illnesses such as typhoid bacillus, cholera, encephalitis, dysentery, meningitis, hemorrhagic colitis, sepsis, gastroenteritis, hemolytic uremic syndrome, cough, septicemia, fever, poisoning, dysentery, diarrhea, vomiting, weakness, and stomach pain. In general, some common antibiotics including tetracycline, norfloxacin, streptomycin, amoxicillin, nitrofurantoin, trimethoprim, gentamicin, nalidixic acid, and cefuroxime, which can inhibit the growth and development of pathogenic bacteria, have been used in the treatment of these foodborne diseases. However, frequent and high-dose use of these commonly used antibiotics leads to the development of antibiotic resistance in some bacteria, posing a threat to public health (Miranda et al., 2014). Sohel et al. (2022) identified a total of 26 pathogenic bacterial strains belonging to 12 different identical species in ice cream samples collected from shops near schools. In their study, they found that among the different antibiotics they used, rifampicin, cefuroxime, methicillin, erythromycin, and ampicillin exhibited the highest resistance, while chloramphenicol, norfloxacin, clotrimazole, ciprofloxacin, tetracycline, and moxifloxacin showed the lowest resistance values. Geçer (2006) stated that the inclusion of 0.02 IU/mL of penicillin in milk during butter processing resulted in flavor and taste defects in the obtained product. They also stated that the butter starter cultures *Lactococcus* spp. and *Leuconostoc* spp., which produce diacetyl that is the dominant flavoring substance of butter during ripening are sensitive to penicillin, and therefore the presence of penicillin in milk prevents the formation of diacetyl. Tona and Olusola (2014)

examined 40 different dairy products in their study on the determination of tetracycline antibiotic residues in dairy products offered for sale. The average level of tetracycline in the butter samples was found to be 0.002 ppm. They also reported that antibiotics found in soft cheese, yogurt, and butter samples were not inhibited by the heat treatment applied during the production process.

Health Effects of Antibiotic Residues in Milk

Due to the widespread consumption of milk and dairy products by people of all ages around the world, the presence of antibiotic residues in milk and their potential impact on human health is of great concern (Khaniki, 2007). Antibiotic residues that pass into the human body through milk and dairy products have various negative effects on health. These effects include mutagenicity, nephropathy (gentamicin), carcinogenicity (sulfamethazine and oxytetracycline), bone toxicity (chloramphenicol), hepatotoxicity, reproductive disorders, and allergy (penicillin). The adverse effects of antibiotic residues on health can be classified into direct (short-term) and indirect (long-term) risks. Among the risks directly affecting human health is the presence of antibiotics passing into milk, which can consequently trigger allergic reactions. Most allergic reactions have been found to be caused by beta-lactam antibiotic residues present in milk or dairy products (Padol et al., 2015). In addition, the long-term effects of beta-lactams include cancer, teratogenicity, reproductive effects, drug resistance, and disruption of the intestinal flora (Priyanka et al., 2014; Treiber and Beranek-Knauer, 2021). Antibacterial substances such as tetracyclines, sulfonamides, and nitrofurans which are commonly used as feed additives in cattle feed, can pass into milk and have been associated with toxicological effects on human health in some cases (Padol et al., 2015). High concentrations of nitrofurans that pass from feed to milk have been shown to cause carcinogenic and mutagenic effects (Gutierrez et al., 2011). Long-term exposure to low levels of oxytetracycline can result in leukocytosis, atypical lymphocytes, lung congestion, thrombocytopenia purpura, and brown discoloration of teeth (Priyanka et al., 2014). Furthermore, gastrointestinal disorders, rash, phototoxic dermatitis, and immunopathological effects on human health are among the residual complications of tetracycline (Redwan et al., 2021). Antibiotic residues have been found to negatively affect the bacterial flora, which helps maintain a healthy gastrointestinal tract in human intestinal metabolism and acts as a barrier to prevent the development of pathogenic bacteria (Darwish et al., 2013). In addition, antibiotic residues in milk damage the human immune system and increase the resistance of pathogenic bacteria in the stomach and intestinal system (Tabak, 2018).

It has been reported that the direct transfer of antibiotics from mother to child and early exposure to antibiotics through contaminated food may increase the risk of obesity in children (Cox and Blaser, 2015). Residues of antibiotics found in animal-derived food products can lead to various complications and problems in individuals, even if they do not exceed the MRL, due to long-term exposure (Treiber and Beranek-Knauer, 2021). An effective detection method needs to be established to prevent antibiotic residues in milk and dairy products. It is necessary to provide basic trainings in order to pay attention to hygiene conditions throughout the country and to increase the level of education of the producers about the use of antibiotics (Sachi et al., 2019).

CONCLUSION

In the food industry, various antibiotic treatments are applied to dairy animals in order to protect animal health, treat various animal diseases, and increase productivity. Antibiotics applied to animals can be transferred into milk in varying amounts and antibiotic residues can also contaminate dairy products as a result of the processing of milk. The antibiotic residues present in milk not only complicates the processing of milk into other products but also poses certain health risks for humans. Weaknesses in the immune system, disruptions in the gastrointestinal flora, and allergic reactions are among these problems. To prevent these problems, Maximum Residue Limits (MRLs) have been established. It is clear that prolonged exposure to antibiotics can lead to health problems. Moreover, exposure to antibiotics results in the formation of resistance genes in both probiotic bacteria and bacteria used as starter cultures. Since these resistance genes are transferred to pathogenic microorganisms by these microorganisms, antibiotic resistance genes can also occur in pathogenic microorganisms.

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