INTERNATIONAL STUDIES IN

ENGINEERING

June 2023

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ASSOC. PROF. DR. SELAHATTİN BARDAK

SERÜVEN YAYINEVİ

Genel Yayın Yönetmeni / Editor in Chief • C. Cansın Selin Temana

Kapak & İç Tasarım / Cover & Interior Design • Serüven Yayınevi

Birinci Basım / First Edition • © Haziran 2023

ISBN • 978-625-6450-62-2

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Baskı & Cilt / Printing & Volume
Sertifika / Certificate No: 47083

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CONTENTS

Chapter 1

EMERGENCY PLANING AND MANAGEMENT: HAZARDOUS WASTE TEMPORARY STORAGE

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1. INTRODUCTION

Natural and man-made disasters can causeloss of life, property and many other great dangers. Whatever the source, it is necessary to act consciously during an emergency, to keep losses to a minimum and to take serious measures to increase security (Yesil, 2017). For this, some studies should be carried out such as marking and setting up an alarm system before the risks occur.

An emergency is an unplanned event that may result from internal or external reasons and that, when it occurs, permanently or temporarily harms employees, the environment, production and facilities, and whose effects may ocur immediately or later (Celik, 2005; Scarneo et al., 2019). It is classified as a minor or major emergency based on its area of impact. The emergency plan, on the other hand, is prepared by following the stages of identifying emergencies, documentation, determining the persons to be assigned, establishing emergency response, drills and renewal of the emergency plan, taking preventive measures for their negative effects, starting from the design or establishment phase for all work places (Aran ve Erol, 2022; Taner ve Bicer, 2022).

A comprehensive emergency action plan is prepared by conducting a hazard assessment to identify physical or chemical hazards inside or outside the work place that could cause an emergency. The plan should describe the structural features and emergency systems of the workplace and how workers will respond to different types of emergencies (OSHA, 2022). Emergency plans are documents that show continuity and need to be renewed periodically. In the case of changes that will cause new emergencies to arise in the work place or its immediate surroundings, the emergency plan is fully or partially renewed in the Regulation on Emergency Situations No. 31615 published in Turkey on 10.01.2021 (Anonymous, 2021; OSHA, 2022). It is renewed every 2 years in very dangerous workplaces, 4 in dangerous workplaces and every 6 years in less hazardous workplaces according to the hazard class (Fidan, 2017).

Although the number of them is limited in the literature, emergency action plan studies for different businesses have been examined. Kilic et al. (2016), according to his research, the emergency action plan of the underground chrome plant in Hatay was evaluated. What to do in case of emergency such as earthquake, gas leak, fire, sabotage, flood and explosion are specified. By determining the duties of employers and employees, it has been evaluated that the loss of life and property can be prevented with the action plan and trainings prepared for emergencies. Duruel (2020), in his study, examined the preparation and implementation of disaster and emergency plans in the stationery production area. Suggestions were made, such as precautions should be taken for explosion and fire, training should be given to employees, and a risk assessment should be prepared. In the research of Oymakapu and Bicer (2021), an emergency action plan sample study was conducted in shopping malls in Kayseri. Standards have been set according to the Regulation on the Protection of Buildings from Fire, the Regulation on Health and Safety Signs, the Regulation on Emergency Situations at Workplaces and the Occupational Health and Safety Law No. 6331. There are suggestions such as the suitability of the buildings, providing employee training, hanging warning signs, and taking precautions against fire. Li et al. (2022), an evaluation and optimization model was applied to predict the evacuation processes in case of a gasleak in a chemical factory and surrounding residential areas. It reveals that the use of optimization strategies, such as ordering an evacuation earlier, significantly reduces the risk of gas exposure during evacuation. Thompson (2003), mentioned in his research the rules that the employer must comply with about fire safety. Emergency action planning begins with a physical survey and preparation of site maps. It includes writing procedures, making key policy decisions, and training employees in these procedures by implementing. Forward planning means effective emergency response in the event of a disaster, limits property damage and protects the environment.

This study includes a sample action plan and precautions to be taken for emergencies that may occur in the hazardous waste temporary storage area. The study has a unique value because there is no research for hazardous waste sites in the literature studies. The subject of study is also of great importance as it is a subject that should be evaluated together with environmental risk analysis and occupational health and safety issues. The aim of the study is to contribute to both the literature and the preparation of an action plan for any facility in practice.

2. Emergencies Determined for Hazardous Waste Area

The steps of the emergency action procedure in workplaces are (1) eliminating the effects of emergency conditions (such as fire, earthquake, flooding, chemical hazards, sabotage) and collecting data that will enable them to make the right decision, (2) creating a work plan, (3) life and taking measures to protect the property, organizing the activities of damage detection, emergency response and rescue teams (Ela et al., 2007).

Emergencies for temporary storage of hazardous waste; fire, earthquake, flood and flood, gas leak and explosion, storm and tornado, chemical leak, lightning strike, epidemic, sabotage and work accident. What to do for these emergencies is examined in detail below.

2.1. Fire

- Systems such as automatic fire detection and response should be used.

- Fire extinguishing options and tubes should be determined according to the material inside.
- Financial liability insurance should be made for the hazardous waste temporary storage area.
- Warning signs such as fire hazard, do not approach with a spark source should be hung.
- Employees should be given a fire drill and training annually.
- Continuous supervision should be applied.

2.2.Earthquake

- Heavy waste should not be stacked on top of each other.
- The electrical installation should be checked annually.
- Cracks in walls must be repaired in the waste area.
- Within the scope of the emergency plan, the sketch showing the escape routes, first aid materials, extinguishing equipment and the location of the emergency assembly area should be kept hanging in visible places.
- Earthquake Situation Action Chart and emergency contact numbers should be hanged in easily visible places.

2.3.Flood and inundation

- The canal and well in the waste area should be cleaned continuously.
- Rainwater channels need to be cleaned.

2.4. Gas leak and explosion

- The electrical installation should be inspectedannually.
- The chemical wastes used should be stored regularly.
- Warning signs should be hung in places where there is a danger of explosion.
- Employees should be given explosion training.
- An Explosion Situation Action Chart should be posted in an easily visible place with contact numbers.

2.5. Storm and tornado

- Hazardous waste temporary storage area should be made of materials that will not be affected by the storm.
- The waste area should be kept locked by the authorized person.
- Waste should not be stacked high.

2.6. Chemical leak

- There must be a Material Safety Data Sheet (MSDS) in Turkish.
- Hazardous wastes can be stored in the temporary storage area for 6 months. It should then be sent to licensed companies.
- Hazardous waste area must be cleaned continuously.
- The Chemical Leakage Situation Action Chart should be available with contact numbers and posted in the appropriate place.
- Waste codes should hang in the temporary storage area.

2.7. Lightning

- Businesses must have lightning rods.
- Metallic items should be avoided.

2.8. Epidemic disease

- Limited persons should be assigned.
- Employees should be vaccinated.
- Entrances should not be allowed except those working in the department.

2.9. Sabotage

- The temporary storage area should be closed.
- The authorized person should be assigned and kept locked in such a way that he/she has the key.
- There must be a security camera.

2.10. Work accident

- A risk assessment should be made for the temporary storage area.
- Health examinations and training of employees should be done periodically.
- Employees should use personal protective equipment.
- Field checks and inspections should be made.
- Near-miss events should be recorded and evaluated.

3. Tasks and Work Plan of Emergency Teams for Emergency Action Plan

Search rescue and evacuation team; to carry out search, rescue and evacuation works of employees, visitors and other persons after an emergency in workplaces. It is the duty of the extinguishing team to intervene immediately in fires that may occur in the workplace, to prevent the spread of fire and to carry out extinguishing activities. It is the duty of the First Aid Team to provide first aid interventions to people who are adversely affected by the emergency. The tasks of the teams should be determined in detail in the emergency action plans. Examples of creating and assigning a sample team are given in Table 1 for the emergency officer, Table 2 for the search, rescue and evacuation team, Table 3 for the fire extinguishing team, and Table 4 for the first aid team.

Table 1. Duties of the emergency officer

Emergency Manager	(1) It makes the necessary arrangements for the deactivation of energy sources and dangerous systems in a way that does not create negative situations and does not affect the protective systems.
	(2)After receiving the emergency notification, she brings the teams to the assembly area, and after receiving the security of the enterprise, he/she goes to the operation area.
	(3) In the event of an earthquake, it will initiate the rescue efforts of people who may be lost or found under the debris.
	(4) In case of chemical leakage, he/she should take the necessary precautions and en sure that the chemical is cleaned.
	(5) It sends the extinguishing team leader to the fire scene and informs the nearest local fire department. It provides intervention to the fire together with other emergency teams.
	(6)In order to eliminate the emergency, they comply with the instructions of the teams arriving at the scene from the relevant organizations outside the workplace.
	(7) After the end of the emergency situation, it is reviewed whether all measures have been taken to prevent the emergency event from recurring.

Table 2. Search, rescue and evacuation team duties

Search, Rescue and Evacuation Team	(1) In the workplace, it should ensure that it is always available by controlling the Emergency (fire) escaperoutes in normal situations.
	(2) Tries to reach the living beings in the fire by using the necessary equipment without endangering their own safety of life.
	(3) Ensures that the rescued creatures are transported to the first aid response area for first aid.
	(4) The emergency manager, the leader of the Protection team and the employer or employer's representative should report the detected malfunctions and ensure that they are corrected and follow up.
	(5) The fire, explosion, work accident etc. occurring in the workplace should work together in coordination with the protection team.
	(6) To protect the belongings and documents, to ensure that the injured are transported in a healthy way. After the fire brigade arrives, he assists the fire brigade in search and rescue evacuation.
	(7) By checking the name of the personel gathered at the assembly point, he/she must confirm whether there are personnel at the scene or not.
	(8) A responsible person from this team takes care of the groups that require special policies, such as the elderly, the disabled and pregnant, in case of emergency.
	(9) To keep the recovered goods and documents in a place to be indicated by the security forces or workplace officials and to deliver them to the relevant persons after the Emergency Situation has passed.

Table 3. Firefighting team duties

Fire Fighting Team	(1) In case of any fire, he/she should not panic and should do the extinguishing Works without putting herself and another person in danger.
	(2) He/She must immediately intervene in the fire that will break out in the areas and sections she is responsible for, extinguish the fire and prevent its spread.
	(3) When they identify any living creature caught in the fire, they notify the rescue and protection team and ensure that they are rescued.
	(4) The team member closest to the fire place should take the existing fire extinguisher and take the wind behind him, break the seal of the device, pull the pin, hold the fire extinguisher coming from the hose end towards the front and bottom of the flame, and move forward by extinguishing it towards the back of the flame.
	(5) The orders of the fire and rescue team chief must be followed during and after the fire.
	(6) He/She must participate in fire training and fire drills held periodically in the workplace.
	(7) He should keep the fire precautions taken in the workplace under constant control. Defects detected should be reported to the fire extinguishing team chief.
	(8) It should asist the fire brigade and other incoming teams.
	(9) After the fire is extinguished, it helps to ensure the cleaning of the fire place by maintaining the environmental safety measures, and together with other teams to determine the location of the fire, the cause of the fire, fire extinguishing works, material damage and other losses after the fire, and prepare a report.

Table 4. First aid team tasks

First Aid Team	(1) Must follow the instructions given by the crew chief.
	(2) In cases where evacuation is required, he/she should count all the employees according to the list of names and asist the evacuation of the workers working in the workplace when necessary.
	(3) It determines the names and conditions of the injured and patients and gives the necessary first aid until the medical first aid arrives or they are taken to the health institution.
	(4) Brings the first aid material to the emergency assembly area and makes the necessary intervention.
	(5) Detects those with serious conditions, requests an ambulance and sends them to the hospital.
	(6) Participates in training activities at the workplace.
	(7) The first aid measures taken at the workplace should be kept under constant control, and any malfunctions detected should be reported to the first aid chief.

DISCUSSION AND CONCLUSION

During the storage and transportation of hazardous wastes, emergencies ocur due to toxic gas emission accidents, human factors that threaten human health, equipment factors, management or environmental factors. Experiencing various emergency situations causes great threats in terms of life safety and social stability. Effective emergency response is an important factor in identifying disaster losses, increasing disaster recovery efficiency and protecting social resources.

Emergency situations that may occur in the hazardous waste temporary storage area can be listed as 10. It can be classified as fire, earthquake, flood and flood, gas leak and explosion, stormand tornado, chemical leak, lightning strike, epidemic, sabotage and work accident. Natural disasters such as earthquakes, fires, floods and floods, sabotage can be solved with less damage by training of employees and exercises (Kilic et al., 2016; Acar, 2019). Gas leakage and explosion are important for emergencies, and early warnings prevent this situation in the study of Liu et al., (2022). Employees should be made aware of the issues to be followed and to provide early warning in epidemics (Dikmen and Bahceli, 2020; Hu and Wang, 2021). Since occupational accidents are mostly caused by employees, occupational accidents can be prevented if training and coordination are provided, risks are evaluated and precautions are taken (Horozoglu, 2017; Caner, 2021). In the study of Duruel (2020), precautions should be taken for explosion and fire and training should be given to employees.

In conclusion; As a result of the evaluation of the emergency action plan for the hazardous waste temporary storage area, the following additional measures and studies can be carried out;

(1) The risk assessment can be prepared taking into account a wider range of events and changing probabilities.

(2) Studies such as risk analysis and environmental risk analysis in terms of occupational health and safety should be calculated by taking into account the changing possibilities.

(3) Emergency action plans should be prepared in integrity, taking into account occupational health and safety and environmental risk analysis studies.

(4) Necessary measures should be increased for activities with high risk scores, monitoring and control should be increased with technological equipment.

(5) A long-term perspective is needed to address changing conditions, development of response capabilities should be ensured.

(6) It is suggested that some types of incidents should be prioritized to resources, training and exercises should be made into consideration of new incidents.

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Chapter 2

THE IMPACT OF ENTERPRISE ARCHITECTURE FRAMEWORK MANAGEMENT APPROACHMENT ON EFFICIENCY IN THE TURKISH BANKING SYSTEM[1]

Cemal GÜMÜŞ[2]

1 This study is derived from the second chapter of the PhD dissertation entitled "The Impact of Enterprise Architecture Framework Management Approachment (EAFM) on Efficiency in the Turkish Banking Sector" written by the author under supervision of Prof. Arman Teksin Tevfik. PhD dissertation acceptance date: 05.10.2018 Haliç University Institute of Social Sciences.

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INTRODUCTION

Changes and developments stemming from environmental factors such as the emergence of new business models in a rapidly developing and changing world, increased competition in the financial sector, equalization and change in customer demands, limit the growth of companies and even prevent them from being a sustainable company. Agility, keeping pace with change and development are among the strategic goals of companies. In our world where technology is developing and changing rapidly, the ability to be aware of and adapt to change is an important driving force, even a necessity, for the sustainable growth of institutions. Providing agile and effective approaches for companies is possible with information technology infrastructures and applications in the business world. In Türkiye, there may be difficulties in adapting to changes and developments due to the fact that the relations between their practices are not defined and documented in institutions, including some corporate companies, or due to the insufficient implementation of the determined and documented rules. Corporate companies are turning to applications that allow relatively small changes to be made, defining and analyzing organizational values, as large changes involve serious risks. In particular, the regulations for which banks are held responsible and standards such as COBIT, ITIL, ISO 27001, CMMI, Enterprise Architecture and Project Management are taken as basis for Information Technologies (IT). Corporate architecture applications strategies, which are among these applications, make a significant contribution to keeping up with the change in terms of covering the organizational structure, IT infrastructure and processes. Enterprise Architecture applications; It plays an important role in achieving a common goal by acting in harmony with other units of the enterprise, aiming to manage and associate subjects such as business architecture, application architecture, data architecture and technology architecture under a single roof. In the first years of corporate architecture applications, it was considered sufficient to manage only the technological infrastructure of the institution. Over time, the use of IT-based applications has gained a richer application area with the addition of data architecture and application architecture to the enterprise architecture concept. Technological infrastructure and investments cannot be considered independent from the strategies and processes of the institution. In order to meet this need, the need for the modern corporate architecture concept used today has emerged. These applications, which combine corporate goals, ways of doing business and IT concept, reach a more inclusive structure and form today's corporate architecture. As a result of the literature research, there are academic studies on the contribution of information technologies to the profitability of institutions. However, it is also possible to reach survey-based reports of some research firms. In the second part, the results related to the benefits revealed as a result of the research conducted under the title of institutional architecture benefits are given. Based on these benefits, a model has been developed in our research model. No academic study has been found in Türkiye on EA in Information Technologies. Although corporate architecture has come to the fore in technology units in the banking and telecom sector in Türkiye in recent years, it has not become widespread enough yet. EA contributes to the creation of simpler, flexible, standard and compatible IT systems, reducing costs, facilitating management, reducing complexity and risk, using communication effectively and using resources efficiently; With EA:

Reducing development and support costs,

- Facilitating data and application migrations
- Increasing the efficiency of system and network applications,
- Easy addressing of security problems,
- Simplifying upgrades and system upgrades,
- Simplifying IT infrastructures,
- Making IT solutions more applicable and affordable,
- Facilitating purchasing decisions,
- Increasing the success rate in projects,
- Delivering products to the market faster and with higher quality,
- Reducing project risks, and costs,
- Working in harmony between business units and IT from the same point of view,
- Benefits such as reducing repetitive work are provided by clearly understanding the needs of business units.

The classical corporate architecture approach, which allows technology management to be carried out in line with corporate strategies, processes and organizational resources, contributes to operational excellence as well as IT developments;

- Faster response to environmental changes and opportunities,
- Associating change projects with corporate strategies,
- Increasing the impact of realized projects on operations,
- Reducing the application development life cycle, and maintenance costs,
- Development of operational procedures,

- Benefits such as reducing the negative impact of organizational changes on sustainability and efficiency are provided.

The implementation of EA, which allows institutions to manage change with an inclusive perspective by combining their different functions in a single environment, attracts attention in our country and its use is increasing due to these benefits. Enterprise architecture is an important framework approach to see the big picture, as it supports issues that require holistic approaches such as IT investments, supporting change programs, linking strategies and goals.

1. ENTERPRISE ARCHITECHTURE

In the world, towards the 1990s, institutional architecture and its basic logic began to come to the fore in institutions that are both scientific and practitioner communities. Benefits of reducing operational operational costs, improving project work, increasing the alignment of business units and information technology (Buckl et al. 2010b:245) are considered as motivators that promote awareness of EA and become more accepted. In general, the EA can be thought of as a structured description of the structure and relationships that can make it the core "management information system" for the enterprise. Therefore, it indicates an integrated expression of different institutional layers in the descriptive models of past, present and future institutions (Niemann, 2006:23). EA covers information technology architectural models and the contents it interacts with. In recent years, EA has been developed for a holistic management approach of IT in a business. Various enterprise architecture frameworks are proposed and used. These enterprise architecture management variants include the Department of Defense Architecture Framework (DoDAF), The Open Group Architecture Framework (TOGAF), the Zachman Framework (Zachman 1987; Department of Defense 2004; The Open Group 2002). Enterprise architecture systems are model-based, as they are diagrammatically defined and their environments form the basis of the approach. The content of the EA models that refer to the sections in the Zachman Framework (Zachman, 1987:27); scope and purpose, business model, systems, technology, component configuration and functions. EA touches on a variety of business areas, including IT and the organization of institutions. He states that although there are various definitions of architecture, it is generally expressed in two approaches. According to one approach, architecture is considered as a prescriptive concept, while the other approach is seen as a descriptive concept (Hoogervorst, 2004:16). Prescriptive definition of architecture; It means that it is seen as a plan or guide for how structures should be created. Over time, the term architecture has been adopted by various scientific disciplines as naval architecture, computer architecture, business architecture, and is used for a broad description. Our research model was examined in 5 sub-dimensions. Based on the model in a previous study, our new research model and sub-dimensions were created as in Figure 1.

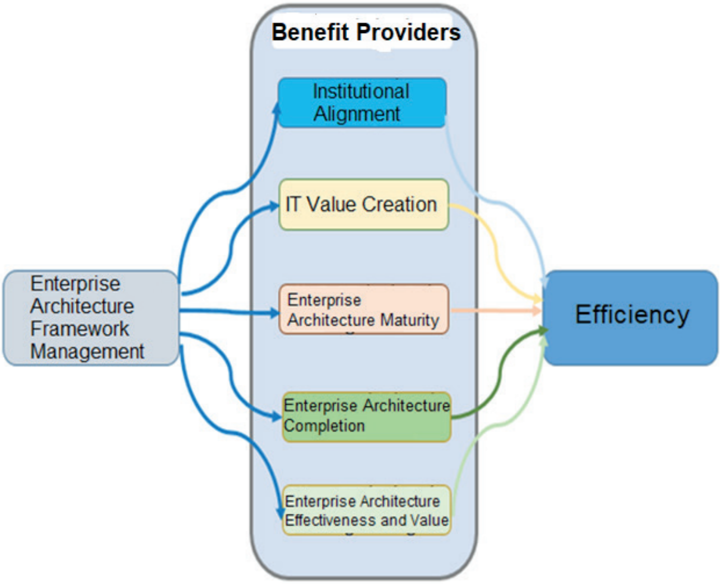

Figure 1: *Research Model and Sub-Dimensions.*

Source: *Tamm, T., Seddon, P. B. et al. (2011:147). How Does Enterprise Architecture Add Value to Organizations? Volume:28 Article:10.*

The research Model and Sub-dimensions detail explained follows:

1.1 Institutional Alignment

The concept of alignment is expressed in different ways from academic expressions. It reveals the basic principle of Alignment that IT will reveal to reflect the business management approach (Sauer and Yetton 1997:29). Alignment is interpreted as the grading of the distribution strategy, in which the tasks, goals and plans of IT are included and executed in the business strategy (Reich and Benbasat 1996:26). Alignment is stated to be the degree of integration and harmony between business strategy, IT strategy, business controls and IT communities (Henderson and Venkatraman 1993:474).

It reveals that IT says strategic alignment can be expanded as a comprehensive objectives and execution processes and information elements used move towards the same goal together (McKeen and Smith 2003). Harmonizing a qualified IT and Business structures means that management makes effective use of IT and IT employees act in harmony with the business strategy, grades and needs of their projects (Luftman and Brier, 1999:8). In response to the questions asked in the investigation; He received answers as “Compliance is a joint arrangement by preserving business capacities and IT together” (Campbell 2005:23). Similarly, strategic alignment, the link between business goals that measure strategy’s progress toward vision, and the goals of key contributors was described as Similar. Persons with primary distribution are groups, divisions, business units, divisions or individual employees who are interested in continuing a successful company. Additionally, alignment, using a rowing analogy; strategic alignment, that is, the whole organization rows in the same direction and at the same pace. In the literature, alignment is also referred to as fit, connection and integration. (Chan 1992:56) defines the degree of mismatch between your work and the target business strategy as the IT strategy. Henderson and Venkatraman (1993), when looking at the relationship between external surgery and internal infrastructure and supervision, they also look at Functional integration in terms of workforce - IT relationship. The link is narrowed down to "the relationship between business and IT" (Reich and Benbasat 1996:18). This operation and others are examples of connection, harmony (Luftman, J., Pap, R. and Brier, T. 1999:3) and fusion, although there are sometimes subtle differences, disposing rather than disposing by alignment. housing as a movement. Enterprise alignment means that the subunits of a storage unit have a shared understanding of their strategic goals and are scaling towards achieving that growth. The harmonious working of corporate alignment between business units and IT has been widely considered and interested (Chan and Reich 2007:4). It is stated that the main purpose of business units and IT cohesion should be closely informed of the IT boundary and the resulting outputs, business speed and operations, and the contents should be compatible (Henderson and Venkatraman 1993:9). Business and IT reconciliation aims to provide the best possible results for the critically important IT outputs, weighted strategic needs that an organization invests in. However, it is not just business-IT compatibility that poses a challenge in large and complex organizations. Alignment is not only an opportunity, a challenge in functional areas such as sales and marketing, but sometimes also includes various discounts and content in corporate and different strategic business units horizontally (Reynolds et al. 2010:8).

1.2 IT Value Creation

It is used to optimize and evaluate proposed IT investments. Predefined valuation criteria typically consider business needs and opportunities, costs, benefits, and risks associated with the investment. IT investments and manufacturing are divided into appropriate portfolio categories such as IT systems, transaction, information and strategic applications, and IT infrastructure. High-level resource allocation decisions are made between these categories. Each of the IT portfolio categories is managed, funded and prioritized separately. Post-deployment reviews are typically done to evaluate the true success of the IT investment project against the original business case. That is, it is done to identify targeted business needs, opportunities, costs, benefits and risks. After commissioning, the analyzed information is compiled and the "lessons learned" from the project are reflected to all interested parties.

1.3 Enterprise Architecture Maturity

An organization's operating model consists of its core organizational structure, core processes, culture, management systems, and information technology. The operating model chosen defines a company's business process integration and standardization needs.

Business architecture is the business description of organizations' business processes and critical elements such as the business's customers, stakeholders, and organizations. Information architecture defines how critical data and information needed to support the business is distributed and managed. The application architecture consists of a portfolio of applications and IT systems that support organizational and business process needs. The technology architecture includes definitions of what supporting technology is involved to provide an environment for applications. IT infrastructure, security, management, networking, and other capabilities are required to support enterprise and business processes. The transition strategy is a roadmap and master plan on how to achieve the organization's vision for existence through an interim transition. The development of the transition plan is based on a gap analysis of the target and current situations.

1.4 Enterprise Architecture Completion

The Enterprise Architecture completion defines EA's approach to IT management in the domains of business architecture, information architecture, application architecture, and technology architecture. It covers all aspects of transition strategies and the management of strategic decisions.

Business architecture defines corporate business management by encompassing critical elements such as the organization's business processes, customers, stakeholders and organizations. Information architecture defines how to distribute and manage the critical data and information needed to support the business. The application architecture consists of the application catalog and IT systems that support organizational and business process needs. The technology architecture includes the definition of what technology is involved in providing an environment for applications.

The enterprise needs IT infrastructure, security, management, networking and other capabilities to support business processes. The transition strategy is the roadmap and master plan on how the organization's vision of existence will be achieved through an interim transition. The development of the transition plan is based on a target and baseline gap analysis.

1.5 Enterprise Architecture Effectiveness and Value

Companies face increasing requirements to adapt to both flexibility and efficiency and cost effectiveness. Information technologies have to be managed well as they become more complex. Otherwise, it may limit a company's ability to change. Enterprise architecture is approaches designed to enable companies to derive value from IT and more easily manage and discipline change.

2. DIFFICULTIESINSPREADINGENTERPRISEARCHITECHTURE

Zachman (1999) explains four reasons why EA has not been widely used enough.

- Architecture presents an unusual new culture and its benefits are difficult to measure.
- EA is not considered essential as a reason for survival in large institutions.
- How to do the whole EA is not known enough.
- EA implementation and adoption takes time and effort.

Baker and Janiszewski (2005) argue that EA is not widespread enough and why institutions have difficulties in compliance with two claims:

- EA is not easily implemented and institutions have to design their own processes.
- The EA results are very difficult to explain and communicate, and the inability to connect and interact in institutions makes it difficult to use EA as a business enabler.

EA documentation is a time-consuming task. However, without proper and adequate documentation, it is impossible to manage EA with only the knowledge that experts know and have in mind. Some organizations have not been able to adapt to the EA because it requires excessive documentation. He argues that this may be true, especially if an organization's goals are very ambitious. Appleton (2004) states that an organization is not a deterministic system whose behavior can be manipulated by direct actions. The larger institutions become, the harder it is to "engineer" them to act as a single entity. An organization is always dependent on both its internal characteristics and its operational characteristics. Appleton argues that while EA establishes the discipline needed for corporate transformation, it must be the right kind of discipline. It should be noted that with the right type of discipline, EA does not try to fix everything. To avoid trying to specify everything, it is necessary to determine the scope of enterprise architecture activities. In small or medium-sized institutions, it is sufficient for EA activities to be at the enterprise level. In large organizations, EA activities are needed at all business levels, such as a division or business unit (Campbell and

Mohun 2007). To manage the appropriate level of guidance and control, Malan and Bredemayer (2002) suggest considering a minimalist approach, keeping the architectural decision as small as possible. The organization should carefully define what decisions are at the architectural level at the enterprise level and what decisions can be made at narrower EA domain levels, such as the individual business unit level, while maintaining integrity. It is important to disseminate the architectural decision in appropriate language. Because too much power, centralized guidance and constraints, the institution may encounter resistance because of trying to use it. According to Burke (2004:17), institutions usually have the right EA vision and strategy, but fail to implement it. He argues that the problems with EA are mostly cultural, structural and organizational. Because EA is a tool for change, people can also resist tools that promote change. However, Burke (2004) states that it is important to understand that EA is not the one who manages the change itself. Changes in business requirements and operating environment are the main drivers of change, not EA. The role of it is to create an adaptive framework in which the creativity of the organization's stakeholders can be applied (Appleton 2004). EA is based on information technology development. While it includes business architecture and thus describes the business business model, EA practitioners may have a separate Business Process Management (BPM) or Total Quality Management (TQM) initiative. In such cases, it has failed to integrate with the organization's core resources. Enterprise Architects often have IT know-how and this experience is considered an advantage for EA. For example, Baker and Janizewski (2005) state that institutional architects are developing in the field of technical architecture. It also mention that in order to explain EA to the personnel in the business units and have it accepted, they must have work experience and knowledge. IT knowledge and experience also affect how organizations use it. Campbell and Mohun (2007) say that most organizations use EA to manage their technology and infrastructure. It must offer more to meet business needs and the enterprise architecture team must focus more on the business partners. Adoption of any approach, tool or framework management planned for the organization to improve its operations should be taken as an investment. The benefits of EA may not be obvious and it may take time to show success, and an organization may have difficulty adopting EA and building a very strong business case for adoption. On the other hand, many benefits are obtained if it is adopted and fully used in enough institutions, such that some of its positive contributions can be received in a short time. (Jukko Perko, 2008)

3. THE IMPACT OF ENTERPRISE ARCHITECTURAL FRAMEWORK MANAGEMENT APPROACHMENT ON EFICIENCY IN THE TURKISH BANKING SYSTEM.

The aim of this research is to examine the effect of Enterprise Architecture Framework Management Approachment (EA) on corporate efficiency in banks.

In line with this goal, it is aimed to reveal the effect of EA on productivity through one-to-one interviews and survey-based research with experts and managers in the banking sector and technology companies of banks in Türkiye.

Different approaches to corporate architecture have been introduced over time and their application is increasing. With this study, it is thought that the positive effect on productivity in EA and banks will be investigated and it will contribute to attracting more attention in the academic field and in businesses. In the preliminary studies, feedback was received in one-on-one interviews with bank managers at various events that the work was very exciting and important. Such motivational feedback throughout the research increased our concentration and willingness to work.

3.1 Universe and Sample

In academic studies, the definitions of universe and sample are generally stated with similar meanings as follows. "The universe is the group that constitutes the field of study of the researcher, whose example he chooses and from which he generalizes the results. The universe is in two parts, the ideal universe and the realistic universe. The ideal universe is one where there are no constraints for the researcher. The realistic universe, on the other hand, is the universe that the researcher creates by considering certain constraints. (Altunışık et al. 2012: 132-133). Considering this definition, we determined the universe as the Banking sector operating in Türkiye. 58 Banks operating in Türkiye, our universe, employ 191,000 personnel (https://www.tbb.org.tr/tr/banka-ve-sektor-bilgileri/statistiki-raporlar/mart--2023---bank, -employee-and-branch-information-/6165 Access: May 2023).

Sampling; "It is the process of forming a group of sub-elements, consisting of a certain number of subjects from the group, in such a way as to represent the large group (the universe) from which they were selected for a study. The purpose of sampling is to provide the researcher with the knowledge that he can make generalizations about the universe without examining the entire universe. Sampling techniques are divided into probability-based and non-probabilistic. In probability-based sampling, each element in the population has an equal and independent chance of being selected. In non-probabilistic sampling, some elements in the universe have a higher chance of being included in the sample than other elements" (Altunışık et al., 2012: 132). Sekaran (1992: 253) states that the sample size required for a population size of 1,000,000 in the acceptable sample table for certain universes is 384. The population size in this study is the total number of employees of 58 Banks in Türkiye, 191,000 people, and the ideal sample size for this study was determined as a minimum of 384, according to Sekaran's acceptable sample size for certain universes.

3.2. Research Methods

Interviews done with 16 bank managers who have over 50 branches in Türkiye. In a sample of 524 participants, 127 ones who left the survey incomplete that were excluded from the evaluation. After studying the data, 397 survey data analyzed with statistical methods such as CFA, ANOVA, and SEM analysis.

In the research, the data collection tool was used over the internet and the questionnaire system was used. Data were analyzed using SPSS 24 and AMOS 24 package programs. The questions developed and asked in a five-point Likert scale. It is assumed that the respondents are familiar with the concept of corporate architecture. When the demographic structure of the respondents participating in the survey is examined; 83.1% of the participants were found to be in the 25-44 age range. These data gave us the conclusion that the survey participants consisted of experienced people.

When the education level of the participants is examined, 90.4% of them are at the level of undergraduate and graduate degrees. High school graduates were not included in our survey. The education level of the participants was very high. It can be said that this situation is expected results for the IT sector. When the banking sector experience of the participants is examined, it is understood that 60.9% of them have banking experience between 4-15 years. It was concluded that our survey was answered by experienced IT personnel in the banking sector. When the working time of the participants in the current bank is examined, it is concluded that the high rate of 73% is mainly based on the personnel working in the same bank for a maximum of 9 years. According to these data, it is understood that the personnel in the bank IT units do not stay in the institutions they work for very long. When the answers given to the question of how many years have banks been using EA are examined, the rate of those who say that they have been using it for 6 years at most is 58.2%. In our study, it was concluded that it is quite new in our country. It is known that the research subject has received increasing attention in our country in recent years.

Table 1: *Data Set Questions and Cronbach Alpha Value.*

No	Anket Soruları	Cronbach's Alpha
1	Our IT strategy is aligned with our business strategy.	.968
2	There is an appropriate IT governance structure and mechanism that facilitates the implementation of our IT strategy.	.967
3	IT successfully supports our corporate operating model and business processes.	.967
4	Our business unit and functional level architecture is aligned with our enterprise level architecture.	.968
5	We have an effective management of the IT control framework with clearly defined roles, responsibilities and accountability.	.967
6	We are aware that IT has a high impact on business continuity.	.968

7	IT is able to rapidly adapt and respond to new and changing requirements in the enterprise.	.968
8	Our approach to IT performance measurement is an effective way to measure how IT delivers services aligned with our corporate strategies.	.968
9	The business model in our organization is an effective way of evaluating IT investments.	.967
10	We have a procedure to ensure that our IT investments align with our enterprise architecture.	.967
11	We have a procedure for post-migration review that is used to evaluate the success of IT investment projects and to share "lessons learned".	.967
12	In our institution, our operation model that directs and coordinates IT has been clearly determined.	.967
13	Our corporate strategy is clearly defined to guide and coordinate IT.	.966
14	Our senior management has clearly defined the role of IT in managing our operations model and corporate strategy.	.967
15	We focus on the needs of our business units and functions. Our corporate architecture mainly consists of applications for business unit functions and related infrastructure.	.967
16	We focus on making IT an enterprise-wide asset by creating a standard IT infrastructure. Efforts are being made to increase IT efficiency by reducing IT costs.	.967
17	We focus on sharing the necessary information to establish standard business processes at the corporate level and to ensure business and operational efficiency.	.967
18	We focus on building reusable application and business process components for strategic agility and better integration between business units and IT.	.967
19	At what level do you think your Business Architecture maturity level is in your organization? (Business architecture definition: defines corporate business management, covering critical elements such as the organization's business processes, customers, stakeholders, and organizations.)	.967
20	At what level do you think your Information Architecture maturity level is in your organization? (Information Architecture definition: defines how to distribute and manage the critical data and information needed to support the business.)	.966
21	What is your Application Architecture maturity level in your organization? The application architecture consists of the application catalog and IT systems that support organizational and business process needs.	.966
22	What is your Technology Architecture maturity level in your organization? (Technology architecture definition: Includes a definition of what technology is involved in providing an environment for applications. The organization needs IT infrastructure, security, management, networking, and other capabilities to support business processes.)	.967
23	What is your transition strategy maturity level? (Transition strategy definition: it is the roadmap and master plan on how to achieve the vision of the organization's existence through an interim transition. The development of the transition plan is based on the target and current situation gap analysis.)	.967
24	What is the level of business-oriented use of enterprise architecture in your institution?	.966
25	What is the level of your ability to share and reuse information?	.967
26	As an output of your enterprise architecture efforts, at what level is your level of improvement in your business processes and services?	.967
27	What is your IT application development/improvement level as a result of your enterprise architecture activities?	.966

3.2.1 Analysis and Findings

Demographic information of the study is as in the Table 2 below.

When the participants of the study examined, 3% of the participants in the sample of 397 people were in the age group of 18-24, 40.3% were in the age group of 25-34, 42.8% were in the age range of 35-44, 13.6% were in the age group of 45-54. 55 years Age and above participants did not join in our survey. As it can be understood from the data obtained, the participants consist of experienced people. When the education level of the participants was examined, it was seen that 6.5% of them were at the doctorate level, 39.3% at the graduate level, 51.1% at the undergraduate level and 2.5% at the associate degree level, and it was seen that the high school graduates were not included in our survey. In the light of these data, it was determined that 97.5% of the respondents who participated in the survey had at least undergraduate level of education. It was observed that the education level of the participants was high. We can say that these figures are expected results for the IT sector. When the banking sector experience of the participants is examined, it is seen that 16.6% have worked in the banking sector for 0-3 years, 35% for 4-9 years, 25.9% for 10-15 years and 21.7% for 16 years or more. . According to these data, it is understood that 83.4% of the participants have a banking sector experience of at least 4 years or more. It is understood that our questionnaire was answered by experienced IT personnel. When the working time of the participants in the current bank is examined, 37.5% of them are 0-3 years, 35.5% are 4-9 years, 15.4% are 10-15 years and 11.3 are working in the bank where they are 16 years or more. . According to these data, it was concluded that the personnel in the IT units did not stay in the institutions they work for very long. It has been understood that 37.5% of them have worked in their current bank for 3 years or less. Employee circulation in the Information Technologies sector is a well-known situation, and a similar result was obtained in our research. When the answers given to the question of how many years have banks been using EA are examined, 26.2% of them are 0-2 years, 32% are 3-6 years, 22.2% are 7-10 years and 18.1% are 11 years or more. Only 1.5% of the participants that they use did not answer this question. In the light of these data, it can be concluded that the use of EA has increased in Türkiye in recent years. It has been observed that 58.2% of the banks have been using EA for 0-6 years. It is estimated that this issue has received increasing attention in our country in recent years. The data supports these predictions.

Table 2: *Participant Demographics*

Demographics Number Percentage		**Number**	**Percent**
Age	18 - 24	12	3.0
	25 - 34	160	40.3
	35 - 44	170	42.8
	45 - 54	54	13.6
	Unanswered	1	0.3
	Genel Toplam	**397**	**100**
Education	Associate Degree	10	2.5
	License	203	51.1
	Master	156	39.3
	Doctoral	26	6.5
	Unanswered	2	0.5
	Grand Total	**397**	**100.0**
How many years have you been working in the banking industry?	0 - 3 years	66	16.6
	4 - 9 years	139	35.0
	10 - 15 years	103	25.9
	16 years and above	86	21.7
	Unanswered	3	0.8
	Grand Total	**397**	**96.7**
How many years have you been working in your current bank?	0 - 3 years	149	37.5
	4 - 9 years	141	35.5
	10 - 15 years	61	15.4
	16 years and above	45	11.3
	Unanswered	1	0.3
	Grand Total	**397**	**100**
How many years has Enterprise Architecture been used in your organization?	0 - 2 years	104	26.2
	3 - 6 years	127	32
	7 - 10 years	88	22.2
	11 years and above	72	18.1
	Unanswered	6	1.5
	Grand Total	**397**	**100**

3.2.2 ANOVA Tests on Sub-Dimensions of Demographic Variables

The effects of demographic variables such as the participants' age, education level, industry experience, experience in the institution they work in and the experience of using EA on 5 sub-dimensions were examined.

ANOVA Tests on Sub-Dimensions of Current Bank Experience: As shown in the Table 3., the mean level of Enterprise Architecture Completion is higher for the personnel working in the current institution for 16 years or more than the personnel working for 0-3 years, and statistically Significance= 0.028 and it is significant at the 95% confidence level since it is less than 0.05.

Table 3: *Enterprise Architecture Complementary Multiple Comparisons.*

Dependent Variable	(I) How many years have you been working at your current bank?	(J) ow many years have you been working at your current bank?	Average Difference (I-J)	Std. Mistake	Meaningfulness
EA Completion	0 - 3 yıl	16 yıl ve üzeri	-.25218	.09045	.028

As shown in the Table 4, only our H20 hypothesis is that the average level of Enterprise Architecture Completion is higher for the personnel working for 16 years or more in the current institution compared to the personnel working for 0-3 years, and statistically Significance= 0.028 and it is significant at the 95% confidence level as it is less than 0.05. out.

Table 4: *Hypotheses on Sub-Dimensions of Current Bank Experience.*

Factor Code	Factor Description	Sig.	Does it make sense?	The dependent variable	Hypothesis Result
KT	KM Completion	0.032	Yes	Banking Experience	H20:Acceptance

In order to examine the variances between which groups after the homogeneity tests, the results of the "Multiple Comparisons" between the SPSS program and Tukey tests in 5 sub-dimensions and the duration of EA use in the institution where the respondent works are shown in the Table 5.

Table 5: *Table of Multiple Comparisons of EA's Term of Use.*

The dependent variable	(I) How many years has the EA been used in your institution?	(J) How many years has the EA been used in your institution?	Average Difference (I-J)	Std. Mistake	Meaningfulness
Enterprise Architecture Completion	0 - 2 years	3 - 6 years	-.29044*	.06402	.000
		7 - 10 years	-.45754*	.07012	.000
		11 years and above	-.65491*	.07422	.000
	3 - 6 years	7 - 10 years	-.16711	.06714	.063
		11 years and above	-.36448*	.07141	.000
	7 - 10 years	11 years and above	-.19737	.07693	.050
IT Value Creation	0 - 2 years	3 - 6 years	-.27263*	.08841	.012
		7 - 10 years	-.49119*	.09683	.000
		11 years and above	-.61437*	.10250	.000
	3 - 6 years	7 - 10 years	-.21856	.09273	.087
		11 years and above	-.34174*	.09863	.003
Enterprise Architecture Effectiveness and Value	0 - 2 years	3 - 6 years	-.39137*	.09914	.001
		7 - 10 years	-.55504*	.10858	.000
		11 years and above	-.85725*	.11493	.000
	3 - 6 years	11 years and above	-.46588*	.11059	.000
	7 - 10 years	11 years and above	-.30221	.11913	.056
Enterprise Architecture Maturity	0 - 2 years	3 - 6 years	-.27337*	.08833	.011
		7 - 10 years	-.45000*	.09674	.000
		11 years and above	-.62734*	.10240	.000
	3 - 6 years	11 years and above	-.35397*	.09853	.002
Institutional Alignment	0 - 2 years	3 - 6 years	-.25360*	.07601	.005
		7 - 10 years	-.47452*	.08324	.000
		11 years and above	-.59555*	.08811	.000
	3 - 6 yeras	7 - 10 years	-.22092*	.07971	.030
		11 years and above	-.34195*	.08478	.000

Our hypotheses H21, H22, H23, H24 and H25 were accepted as the Significance value for the banks' PF usage periods was 0.000<0.05 in all sub-dimensions. The results of the research hypotheses are shown in detail in Table 6. According to these data, the duration of use of the institutional architecture in institutions was statistically significant at the 95% reliability level on the sub-dimensions.

Table 6: *Hypotheses on Sub-Dimensions of EA Duration.*

Factor Code	Factor Description	Meaningfulness	Dependent Variable	Hypothesis Result
IA	Institutional Alignment	0.000	EA Usage Period	H21: Acceptence
EAM	Enterprise Architecture Maturity	0.000		H22: Acceptence
ITVC	IT Value Creation	0.000		H23: Acceptence
EAV	Enterprise Architecture Effectiveness and Value	0.000		H24: Acceptence
EAC	EA Completion	0.000		H25: Acceptence

3.3 Structural Equation Model (SEM)

The data we obtained in this part of our research were analyzed with the Structural Equation Model (SEM) method. AMOS 24 application was used in SEM analysis. SEM is not a single statistical method. It is the commonly known name of more than one statistical method (Cokluk et al. 2012:252). Structural equation models, which have been used in many fields such as psychology, sociology, education, economy and marketing in recent years, are an analysis method consisting of a combination of multivariate statistical methods (Kayacan and Gültekin, 2012:12). SEM is preferred to be used in many different areas because it takes into account the measurement errors of the observed variables, which differ from the known and frequently used methods. Another important reason why SEM is generally preferred in scientific studies is that it allows developing, estimating and testing multivariate models that include both the direct effects from one variable to the other, and the effects between two variables, caused by the effect of a mediator variable. The complexity and difficulty of analyzing these multivariate models cause SEM applications to be preferred in the analysis process (İlhan and Çetin, 2014: 27). In SEM analysis, Confirmatory Factor Analysis (CFA) is used to confirm the factor groups determined as a result of a theory or previous experimental research, rather than revealing a factor structure. The theoretical structure of CFA tests the observed data (Terblanche and Boshoff, 2006:24). Within the framework of SEM, the main hypotheses on productivity were formed and presented graphically in the Figure-6.1.

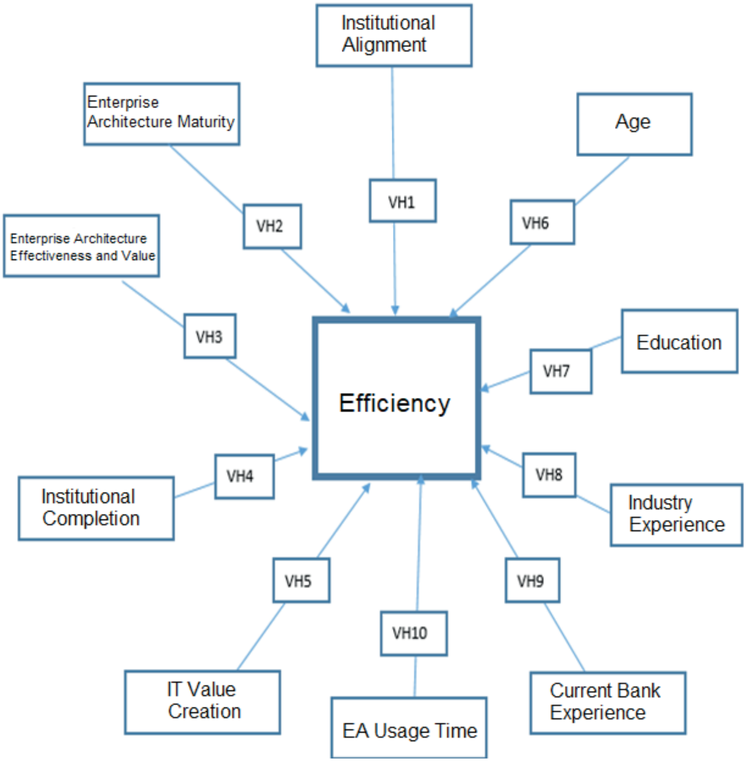

Figure 2: *EA Efficiency Tendency Structural Equation Modeling.*

As a result, in the SEM analysis, firstly, the structural equation model was tested with the help of the fit values and the most suitable model reached.

When the findings of our main hypothesis tests on productivity from the Structural Equation Model are examined, as in the Table 6.8. "Enterprise architectural maturity has an effect on productivity" Our HV2 hypothesis was found to be statistically significant at 95% confidence level and our hypothesis was accepted. "Enterprise Architechture Completion has an effect on productivity" Our HV4 hypothesis was found to be statistically significant at 90% confidence level and our hypotheses were accepted. The results are shown in the Table 7.

Table 7: *Efficiency Main Hypothesis Findings.*

Factor Code	Factor Description	Meaningfulness	Dependent Variable	Hypothesis Result
EAM	Enterprise Architecture Maturity	0,042	Verimlilik	HV2:Acceptence
EAC	EA Completion	0,078	Verimlilik	HV4: Acceptence

4. CONCLUSION

The findings obtained as a result of the research; It will inform the banks, finance sector, telecom sector, technology companies and all institutions working in close cooperation with technology that EA can make a significant contribution to the achievement of the strategic goals of the institutions and it is thought that it will encourage companies to use EA. In the first part of the questionnaire shown in the Table-1. Age, education level, sector experience, current bank experience of the participants and the frequency and percentage distributions of the banks' EA usage periods were calculated. In the second part of the questionnaire, factor analysis and structural equation model analyzes were conducted to examine the effects of "Enterprise Alignment", "IT Value Creation and Efficiency", "Enterprise Architectural Maturity", "Enterprise Completion" and "Enterprise Architecture Efficiency and Value" on EA. In the third part of the questionnaire, questions were asked to understand the participants' thoughts on the effects of EA on Productivity. With confirmatory factor analysis, model fit values were examined in order to examine whether the factor structure was compatible with the research model. According to confirmatory factor analysis, it was seen that the factor structure used in the study and based on theoretical foundations was compatible with the research model. When the tendencies of the participants on the effect of productivity and the consistency of their answers to the surveys were examined, no statistically significant difference was found that the effect of EA on productivity was "Very low". Those who thought that the productivity effect of the participants were "high" and "very high" showed that the productivity effect was also "high" and "very high" in general, which showed that they reflected their thoughts consistently.

It was found that the current institution experience of the staff (H20) had an effect on the Institutional Completion sub-factor and it gave statistically significant results. When examined in detail, it is understood that EA indirectly contributes to efficiency in banks as the experience of the personnel in the institution increases.

H21, H22, H23, H24 and H25 hypotheses regarding the effect of EA usage time factor in banks on all sub-dimensions were accepted. It has been seen that EA has a positive contribution to efficiency as banks use EA and as their experience increases.

The data obtained in the last part of the study were analyzed by SEM method. AMOS 24 package program was used for SEM analysis. Among our hypotheses for the direct impact of sub-dimensions and demographic information on productivity, the "Institutional Architectural Maturity" (HV2) hypothesis and our "EA Completion" (HV4) hypothesis were statistically significant. According to our model, the productivity effect of the sub-dimensions of "Enterprise Architecture Effectiveness and Value", "Enterprise Alignment" and "IT Value Creation" could not be determined. The fact that the institutional alignment does not have a direct effect on productivity should also be investigated and the reasons should be examined. Research results have been reached that the corporate alignment factor benefits companies in the world. In this study, among the 5 sub-factors in the model presented in the Figure-1, the aforementioned "Corporate Architectural Maturity" and "Enterprise Architecture Completion" factors were statistically significant and it was concluded that they had a positive effect on productivity. The fact that the institutional alignment does not yield statistically significant results is thought to be due to the insufficient maturity level of harmony between IT and business units in Türkiye.

In our research, with the findings on the effect of the EA approach on productivity, awareness is increased and it contributes to a more effective management if the technology units act in harmony with the corporate strategies. It is thought that research will be a driving force for sector managers.

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Chapter 3

APPLICATIONS OF ULTRALIGHT OVERHEAD CONVEYOR SYSTEMS IN THE LOGISTICS SECTOR

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This study has been derived from my PhD thesis: Konzeptentwicklung ultraleichter Elektrohängebahnsysteme und deren Bewertung für Logistik-Applikationen, Fakultät für Ingenieurwissenschaften, Lehrstuhl Transportsysteme und-logistik der Universität Duisburg-Essen, Gutachter: Prof.Dr. -Ing. Bernd Noche&Prof.Dr.-Ing. Bernd Künne,2015

Introduction

In today's fast-paced and ever-evolving logistics sector, the efficient movement of goods plays a pivotal role in ensuring timely and cost-effective delivery. Traditional material handling methods such as manual labor, forklifts, and conventional conveyor systems have limitations that can hinder productivity and flexibility (Myhre, Transeth, & Egeland, 2015). However, with advancements in technology, ultralight overhead conveyor systems have emerged as a promising solution to overcome these challenges. This chapter work explores the applications of ultralight overhead conveyor systems in the logistics sector, focusing on their benefits, implementation challenges, and potential future developments.

Overhead conveyor systems utilize suspended tracks to transport goods, allowing for the efficient utilization of space, improved handling capabilities, and enhanced workflow management. These systems typically consist of a network of motorized carriers that move along the tracks, carrying various types of loads such as cartons, totes, and even individual items (Aylak, Alias, Hendrikse, & Noche, 2015). The concept of overhead conveyors has been employed in different industries, including manufacturing and warehousing, for several decades. However, the recent development of ultralight materials, advanced control systems, and automation technologies has paved the way for their increased adoption in the logistics sector.

Ultralight overhead conveyor systems represent a significant advancement in conveyor technology, leveraging lightweight materials, modular designs, and advanced automation capabilities. Ultralight overhead conveyor systems can be defined as lightweight conveyor systems that utilize overhead tracks and hanging trolleys or carriers to transport goods and materials within the logistics sector (Aylak, Cantepe, Ruzayqat, & Noche, 2013). These systems are designed with lightweight materials, such as aluminum or carbon fiber, for the conveyor structure, resulting in a flexible and efficient solution for material handling (Aylak, Noche, Cantepe, & Karakaya, 2013). The benefits of ultralight overhead conveyor systems are manifold. Firstly, their suspended design eliminates floor-level obstructions, allowing unimpeded movement of personnel and other equipment, thus enhancing safety and reducing the risk of accidents (Belsky et al., 2019). Secondly, the versatility of these systems enables them to navigate complex layouts, including mezzanines, multi-level structures, and tight spaces, optimizing the utilization of available floor area (Aylak & Noche, 2013b). Additionally, their modularity facilitates scalability and adaptability, enabling quick reconfiguration or expansion to accommodate changing operational requirements (Aylak & Noche, 2013a).

Despite their numerous advantages, the implementation of ultralight overhead conveyor systems in the logistics sector presents certain challenges.

Some of these challenges include initial investment costs, integration with existing infrastructure, maintenance requirements, and compatibility with different load types (Belsky et al., 2019). This research chapter will explore these challenges in detail and propose strategies to overcome them, ensuring successful deployment and long-term operational effectiveness (Aylak & Noche, 2013b). In short, the applications of ultralight overhead conveyor systems in the logistics sector offer immense potential to revolutionize material handling processes. By streamlining operations, enhancing efficiency, and enabling flexible and scalable solutions, these systems can significantly improve the performance of logistics operations (Aylak & Noche, 2013a). Through this research chapter, we aim to provide a comprehensive understanding of the benefits, challenges, and future prospects associated with the implementation of ultralight overhead conveyor systems in the logistics sector.

Evolution of Overhead Conveyors

The use of overhead conveyors dates back to the early 20th century and spans numerous industries. Numerous significant turning points and inventions can be used to chart the growth and evolution of these conveyors.

Overhead conveyors have been used since the early 1900s, when they were mostly employed in manufacturing facilities to move goods and materials. These early systems relied on an intricate web of chains, trolleys, and rails and were usually built with heavy steel components (Zrnić, Đorđević, & Gašić, 2024). In the 1950s, enclosed track conveyors were introduced, marking a significant advancement in overhead conveyor technology. Enclosed track systems featured a closed-loop track design, which provided a more reliable and durable solution compared to the earlier open-chain designs (Ullrich & Ullrich/Günter, 2014). With the advancements in manufacturing techniques and materials, overhead conveyor systems evolved to become more modular and flexible. This allowed for easier customization and reconfiguration to meet changing production requirements. Manufacturers started incorporating modular components, such as bolted tracks and adjustable hangers, making it easier to install and modify the conveyor systems (Engelhardt-Nowitzki & Oberhofer, 2006).

In the late 20th century, there was a significant shift towards using lighter materials in overhead conveyor systems. The adoption of aluminum and other lightweight alloys allowed for the construction of conveyors that were not only lighter in weight but also more corrosion-resistant and energy-efficient (Aylak, Noche, et al., 2013). The development of overhead conveyors was greatly aided by developments in power and control systems. Smoother and more effective material handling activities were made possible by the exact control over conveyor movement made possible by the integration of electric motors, variable speed drives, and sophisticated control algorithms.

A lightweight substitute for conventional steel chain conveyors is the plastic chain conveyor. These conveyors had plastic chains, which were lighter and more flexible in terms of design and arrangement. They also operated more quietly and required less maintenance.

Overhead conveyors' capabilities have changed recently as a result of their integration with Industry 4.0 concepts and automation technology. These days, conveyor systems come with sophisticated software, robots, and sensors that allow for seamless interaction with other automated processes, real-time monitoring, and predictive maintenance.

Technology behind Ultralight Overhead Conveyor Systems

Ultralight overhead conveyor systems represent a significant technological advancement in the field of material handling and logistics. These systems leverage various technologies to enable seamless and efficient transportation, sorting, and management of goods within logistics facilities. This discussion explores the key technologies involved in the design and operation of ultralight overhead conveyor systems, highlighting their contributions to system performance, flexibility, and automation (Aylak, 2015).

A fundamental aspect of ultralight overhead conveyor systems is the use of lightweight materials. Traditional conveyor systems often rely on heavy-duty steel structures, whereas ultralight systems employ materials such as aluminum, plastic composites, or carbon fiber. These lightweight materials provide several benefits, including reduced energy consumption, increased system flexibility, and easier installation (Aylak & Noche, 2013b). The selection of appropriate materials depends on factors such as load capacity requirements, environmental conditions, and cost considerations.

Modular design is a key feature of ultralight overhead conveyor systems. The systems are composed of modular components, including conveyor tracks, hangers, supports, and drive units. These modular elements can be easily configured and reconfigured to adapt to different layouts and operational needs (Aylak et al., 2015). The modularity enables rapid installation, scalability, and reconfiguration, making the systems highly versatile and suitable for dynamic logistics environments.

Ultralight overhead conveyor systems rely heavily on automation to facilitate fast and effective material handling procedures. A range of automation technologies are utilized, including as sensors, programmable logic controllers (PLCs), motorized motors, and human-machine interfaces (HMIs). The conveyor system is powered by motorized motors, which enable exact control over movement and speed. Sensors that identify the presence of objects and enable automated sorting, routing, and tracking include photoelectric sensors and proximity sensors. As the center of control, PLCs interface with various logistics systems, including warehouse management systems (WMS), and coordinate the operation of the conveyor system.

Energy-saving features are frequently used in ultralight overhead conveyor systems to reduce power usage and environmental effect. Variable frequency drives, or VFDs, are frequently used to regulate the conveyor system's speed in order to best utilize energy and adapt to the demands of the load. Furthermore, regenerative braking systems have the ability to transform the kinetic energy produced during braking into electrical energy that may either be recycled inside the system or fed back into the power grid. In the logistics industry, these energy-efficient technology promote sustainability objectives and help save costs.

Logistics operations must be coordinated and efficient, which requires integration with information systems. Enterprise resource planning (ERP), data analytics platforms, and WMS are just a few of the information systems that ultralight overhead conveyor systems can be easily integrated with. Order fulfillment, inventory control, and conveyor system performance may all be tracked in real time thanks to integration. Conveyor system data can be used for performance analysis, decision-making, and operational optimization.

To put it briefly, lightweight overhead conveyor systems use a number of cutting-edge technology to improve the logistics industry's material handling procedures. Enhanced system performance, flexibility, and sustainability are achieved by the implementation of energy-efficient measures, modular design, lightweight material use, sophisticated automation, and integration with information systems. The efficiency and efficacy of ultralight overhead conveyor systems in many logistical applications can be maximized through additional improvements and ongoing research and development activities.

Design Considerations for Ultralight Overhead Conveyor Systems

Ultralight Overhead Conveyor System design plays a crucial role in determining the system's operation, efficiency, and adaptability for different logistical applications. Easy interaction with other logistics operation components, efficient space usage, and seamless material movement are all guaranteed by a well-designed system. Important design factors are covered in this talk, such as conveyor selection, load capacity, drive mechanisms, system layout, and safety measures.

1. System layout

Ultralight Overhead Conveyor System layout design entails examining the floor plan of the establishment, taking into account the necessary space, workflow, and operational limitations. It is necessary to consider elements like the building's shape, the equipment that is currently in place, the storage spaces, and any possible bottlenecks.

2. Conveyor selection

Choosing the appropriate type and configuration of conveyors is crucial in the design process. Ultralight Overhead Conveyor Systems offer a range of options, including monorail, power-and-free, and inverted conveyors. The selection depends on factors such as load characteristics, desired throughput, floor space availability, and material handling requirements. Evaluating the specific needs of the logistics operation helps determine the most suitable conveyor type and layout (Aylak et al., 2015).

3. Load capacity

Determining the load capacity is an essential consideration in Ultralight Overhead Conveyor System design. While these systems are lightweight, they must still meet the demands of transporting various types of goods. Understanding the weight distribution, size, and dimensions of the loads is crucial for selecting the appropriate materials, track structures, and hanger configurations. The load capacity requirements influence the choice of materials and the design of load-bearing components (Aylak, Cantepe, et al., 2013).

4. Drive mechanisms

The drive mechanisms in Ultralight Overhead Conveyor Systems play a critical role in controlling the movement and speed of the conveyors. Motorized drives, typically equipped with variable frequency drives (VFDs), provide the necessary power and control to ensure smooth operation. VFDs allow for adjustable conveyor speeds, enabling flexibility to accommodate different material handling requirements. The design should include considerations for energy efficiency, speed control, and synchronization between multiple conveyor lines (Aylak, Noche, et al., 2013).

5. Safety features

When designing an Ultralight Overhead Conveyor System, safety must come first. The protection of people and property is ensured by incorporating the necessary safety elements. Safety features encompass many elements such as emergency stop buttons, safety interlocks, obstacle detection sensors, and guarding mechanisms that impede unintentional access to moving parts. A safe working environment can be established by designing the system with compliance to safety standards and laws in mind.

Consequently, significant thought must be given to the system layout, conveyor choice, load capacity, drive mechanisms, and safety measures while designing Ultralight Overhead Conveyor Systems. Logistics experts may build dependable and effective conveyor systems that maximize material flow, boost output, and guarantee the security of both people and products by taking these design factors into consideration.

Applications of Ultralight overhead conveyor in Logistics and supply chain sectors

Systems for ultralight overhead conveyors are redefining material handling procedures and increasing operating efficiency in the logistics industry. The following are some important uses for these systems:

1. Goods transport and sorting

Ultralight overhead conveyors excel in transporting various types of goods within a facility. They can efficiently move items such as cartons, totes, and individual products, eliminating the need for manual handling or the use of forklifts (Aylak & Noche, 2013b). The overhead design maximizes the utilization of available floor space by enabling smooth mobility across various regions, including mezzanines, multi-level constructions, and tight spaces. These systems can also be used with automated sorting mechanisms to enable effective item routing and diversion depending on preset parameters, improving order accuracy and productivity.

2. Order fulfilment and e-commerce operations

Systems for ultralight overhead conveyors are essential for optimizing logistical workflows, especially in order fulfillment and e-commerce. They speed up the process of finding items and getting orders ready for shipping by making it easier to pick and pack products efficiently. Through the integration of these conveyors with automated storage solutions like carousels or vertical lift modules and order management systems, the flow of items may be improved, reducing order processing time and boosting throughput.

3. Cross-docking and transshipment

Systems for ultralight overhead conveyors are ideal for transshipment and cross-docking. The direct transfer of goods from incoming to outgoing shipments without the need for long-term storage is known as cross-docking. With the help of these conveyors, goods may be moved quickly between docking stations, guaranteeing efficient transfers, cutting down on handling time, and lowering the requirement for storage space. Overhead conveyors facilitate a seamless and effective transition between modes of transportation in transshipment scenarios, decreasing the risk of damage or loss and assuring fast and correct transfers.

4. Returns processing and reverse logistics

Effective management of returns and reverse logistics is crucial in the logistics industry. Systems of ultralight overhead conveyors that provide an orderly and regulated flow of returned goods can help these operations. They make it possible to systematically sort, inspect, and dispose of returned goods, making it easier to either reintegrate them into inventory or send them to the proper places for refurbishment, repair, or disposal. The overhead design guarantees effective space utilization and facilitates prompt and precise identification of returned items.

5. Lean manufacturing and just-in-time (JIT) supply

JIT supply techniques and lean manufacturing principles are particularly suited for ultralight overhead conveyor systems. They provide the seamless movement of supplies and parts between workstations, guaranteeing uninterrupted production. These conveyors simplify industrial layout, improve workflow management, and lower the possibility of bottlenecks by doing away with the requirement for manual handling or conventional conveyor systems that take up floor space. In order to ensure that components are delivered to the manufacturing line on schedule, JIT supply can be effectively executed by integrating automated replenishment procedures and inventory control systems with overhead conveyors.

These uses demonstrate the lightweight overhead conveyor systems' adaptability and efficiency in the logistics industry. Organizations can save labor costs, increase order accuracy, improve operational efficiency, and improve customer service by making the most of their capabilities.

Benefits of Ultralight Overhead Conveyor Systems

Ultralight overhead conveyor systems offer numerous benefits in the field of material handling and logistics. These innovative systems provide efficient, flexible, and cost-effective solutions for transporting goods within warehouses, distribution centers, and manufacturing facilities. This discussion explores the key benefits of Ultralight Overhead Conveyor Systems, including increased productivity, improved space utilization, enhanced flexibility, and reduced labor costs (Aylak & Noche, 2013c).

Ultralight overhead conveyor systems contribute to increased productivity in logistics operations. These systems enable continuous and automated material flow, eliminating the need for manual handling and reducing idle time. With the ability to transport goods at high speeds and with precision, these systems facilitate faster and more efficient handling, sorting, and distribution of products (Aylak, Cantepe, et al., 2013). The streamlined material flow minimizes bottlenecks and enhances overall operational efficiency. One significant benefit of Ultralight Overhead Conveyor Systems is their ability to optimize space utilization. These systems operate above ground level, utilizing the vertical space within the facility. By eliminating the need for floor-based conveyors or material handling equipment, Ultralight Overhead Conveyor Systems free up valuable floor space. This additional space can be utilized for storage, additional equipment, or other operational needs, maximizing the facility's overall storage capacity and operational efficiency (Aylak et al., 2015).

Ultralight overhead conveyor systems offer enhanced flexibility in material handling operations. These systems are designed to be modular, allowing for easy configuration, expansion, and reconfiguration. With the ability to adapt to changing operational needs and layouts, the conveyor system can be modified to accommodate different product sizes, weights, and shapes. This flexibility enables efficient handling of a variety of goods and facilitates rapid changes in production or distribution requirements (Aylak, Noche, et al., 2013). The possibility for lower labor expenses is a key advantage of Ultralight Overhead Conveyor Systems. These systems reduce the need for manual labor for tasks like loading, unloading, and sorting by automating material handling procedures. Barcode scanning, autonomous routing, and sorting systems are examples of automated features that further minimize the need for human interaction, resulting in lower labor costs and more operational efficiency.

Systems for ultralight overhead conveyors help logistics operations operate more safely and ergonomically. These solutions lessen the possibility of worker strains and injuries by doing away with the necessity for extensive manual lifting, pushing, and tugging of heavy items. Furthermore, safety features reduce the likelihood of accidents or incidents by ensuring a safe working environment through the use of guarding mechanisms, obstruction sensors, and emergency stop buttons. To put it succinctly, these systems provide automated and effective material handling solutions that enhance operating procedures and raise overall operational effectiveness and efficiency.

Implementation Challenges of Ultralight Overhead Conveyor Systems in the Logistics Sector

Ultralight overhead conveyor systems present a number of advantages and prospects for optimizing logistics operations, but their successful deployment necessitates addressing certain problems. To guarantee the successful integration and application of these technologies, it is imperative that researchers and logistics experts equally comprehend these difficulties.

1. Load Capacity and Durability

One of the primary challenges for ultralight overhead conveyor systems is their load capacity and durability. The use of lightweight materials, such as aluminum or plastic, may limit the maximum weight that can be transported. Heavy or bulky items may exceed the capacity of the system, requiring alternative handling methods (Aylak, Noche, et al., 2013). Moreover, lightweight components' endurance could be a problem, especially in harsh industrial settings. In order to make sure that the system can sustain its longevity and endure operating demands, thorough testing and careful material selection are required.

2. System Design and Configuration

It can be difficult to design an effective and well-optimized ultralight overhead conveyor system for a given logistical application. The right configuration including the quantity of conveyor lines, hangers, and routing paths must be determined by taking into account many factors, including the layout of the facility, available space, throughput needs, and load characteristics. Finding the ideal balance between system performance and cost-effectiveness is a challenging challenge that calls for in-depth knowledge and careful consideration.

3. Integration with Existing Infrastructure

Another problem is integrating ultralight overhead conveyor systems with current technologies and infrastructure. In order to integrate the new system into retrofitted existing facilities, adjustments including software integration with other material handling equipment, electrical connections, and structural improvements may be needed. Careful planning and coordination are needed to provide seamless integration with current logistics technologies and procedures, such as automated storage and retrieval systems or warehouse management systems.

4. Maintenance and Serviceability

For ultralight overhead conveyor systems to operate dependably and effectively, proper upkeep and serviceability are crucial. To reduce downtime and increase system availability, routine inspections, preventative maintenance, and quick repair of any component failures are essential. Overhead conveyor accessibility, however, can provide difficulties, particularly in establishments with constrained area or intricate architectures. When designing a system, maintenance ease and spare part availability should be taken into account.

5. Worker Safety and Ergonomics

Considering ergonomics and worker safety are crucial when putting ultralight overhead conveyor systems into practice. It is imperative that workers who handle loading, unloading, and system operation obtain adequate training to guarantee safe procedures and prevent potential risks such crashes or falling objects. Ergonomic elements, such employees' reach and height, should be taken into account to reduce physical strain and boost output.

6. Cost Considerations

The integration, installation, and design of the system are among the major up-front expenses associated with the implementation of lightweight overhead conveyor systems. It is important to carefully weigh the projected advantages and operational efficiencies of these technologies against their cost-effectiveness. When making decisions, factors including return on investment, cost savings from increased productivity, and long-term maintenance costs should be taken into account.

Logistics experts can optimize the advantages of ultralight overhead conveyor systems and remove any obstacles to their effective deployment by tackling these issues. In order to overcome these obstacles and further enhance the functionality and viability of these systems in the logistics industry, research and development activities in the fields of materials science, system design, and automation technologies must continue.

Future Prospects of Ultralight Overhead Conveyor Systems Usage in the Logistics Sector

In the logistics industry, ultralight overhead conveyor systems have already proven to have a lot of promise and advantages. With the need for greater operational efficiency, changing client demands, and technological improvements driving these systems, the future looks bright. The prospects for Ultralight Overhead Conveyor Systems are discussed in this talk, along with developments in automation, integration with new technologies, sustainability, and the possibility of further customization.

1. Advancements in Automation

Future developments in automation hold great promise for Ultralight Overhead Conveyor Systems. These systems have the potential to grow even more intelligent and effective with the further advancements in robotics, AI, and machine learning. Conveyor system performance can be improved by integrating it with automated picking and sorting technologies like robotic arms and computer vision systems. Increased automation can result in less reliance on manual labor, better accuracy, and faster order processing.

2. Integration with Emerging Technologies:

Systems for ultralight overhead conveyors may be able to work with new technologies that are reshaping the logistics sector. Demand forecasting, inventory optimization, and predictive maintenance, for instance, are made possible by the Internet of Things (IoT) by enabling real-time monitoring and data collecting from the conveyor system. Technologies like augmented reality (AR) and virtual reality (VR) can improve worker training by increasing productivity and decreasing process mistakes. The incorporation of these novel technologies has the potential to optimize processes and augment overall efficiency.

3. Sustainability Considerations

Future Ultralight Overhead Conveyor System adoption will be heavily influenced by sustainability factors. The goal of logistics operations is to lessen their carbon footprint and environmental effect. Due to their capacity to maximize space usage, minimize energy consumption, and eliminate the need for floor-based conveyors, Ultralight Overhead Conveyor Systems have intrinsic sustainability benefits. These systems' sustainability profile can be further improved by incorporating renewable energy sources and using energy-efficient components. Tracking and monitoring energy use and emissions can also help with compliance and reporting for sustainability.

4. Enhanced Customization

Better customizability is another of Ultralight Overhead Conveyor Systems' future hopes. The capacity to customize conveyor systems to meet particular needs becomes essential as logistical operations get more varied and intricate. Conveyor height adjustments, variable combinations, and modular designs can facilitate simple customization and adaption to various product kinds, facility layouts, and operational requirements. The degree of flexibility and customisation offered by logistics companies can facilitate process optimization and increase overall efficiency.

Ultralight Overhead Conveyor Systems have bright future potential in the logistics industry. Future adoption and use of these systems will be largely determined by advancements in automation, integration with emerging technologies, sustainability concerns, and improved customization capabilities. Logistics operations may become more competitive, sustainable, and efficient by embracing these future opportunities.

Conclusion

For the logistics industry, ultralight overhead conveyor systems have a number of advantages and bright future possibilities. These technologies have shown to be effective, room-saving, and adaptable ways to handle and move materials in distribution centers and warehouses. Enhanced safety, lower operating costs, better workflow efficiency, and higher production are some of the advantages that were covered.

It's crucial to understand the drawbacks and difficulties that come with Ultralight Overhead Conveyor Systems, though, including their expensive initial prices, limited suitability for specific product kinds, upkeep requirements, and requirement for meticulous system design and planning. To guarantee the successful deployment and application of these systems in the logistics industry, certain factors need to be taken into account. The prospects for Ultralight Overhead Conveyor Systems are bright in the future. Their growth and utilization will be further propelled by advancements in automation, integration with emerging technologies, sustainability considerations, and greater customisation capabilities. These developments will help logistics operations become more competitive overall, more efficient, less dependent on manpower, and more sustainable.

Collaboration, knowledge sharing, and keeping up with technical breakthroughs are crucial for logistics experts, researchers, and industry stakeholders to fully realize the promise of Ultralight Overhead Conveyor Systems. Logistics methods will become even more efficient and sustainable with continued research and development in areas like automation, IoT integration, and sustainability. The logistics sector can use Ultralight Overhead Conveyor Systems as a useful tool to streamline material handling procedures, increase operational effectiveness, and satisfy changing industry demands by utilizing the advantages and overcoming the drawbacks. These systems will continue to be extremely important in determining the direction that logistics takes with proper planning, execution, and continuous improvements.

In conclusion, Ultralight Overhead Conveyor Systems have enormous potential to revolutionize the logistics industry. By becoming widely used, they can result in notable gains in productivity, sustainability, and efficiency.

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Chapter 4

SEDIMENTARY FEATURES OF THE ORHANİYE FORMATION (LUTETIAN) AROUND ORHANİYE-GÜVENÇ (ANKARA, TÜRKİYE)

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Introduction

Offering a narrow spread in the study area; the unit, which consists of cream-colored fossiliferous limestone, sandstone, and mudstone, took its name from Orhaniye Village (Figures 1, 2). Gökten et al. (1988) first defined and named this unit under the name Orhaniye Formation. In this study, the unit was studied under the name of Orhaniye Formation.

The Orhaniye Formation outcrops in the study area, along the line of Orhaniye Village and Güvenç Village, in the south and north of Lezgi Village, and Karyağdı Hill, Akpınar Hill and Dikbayır Hill (Figure 1).

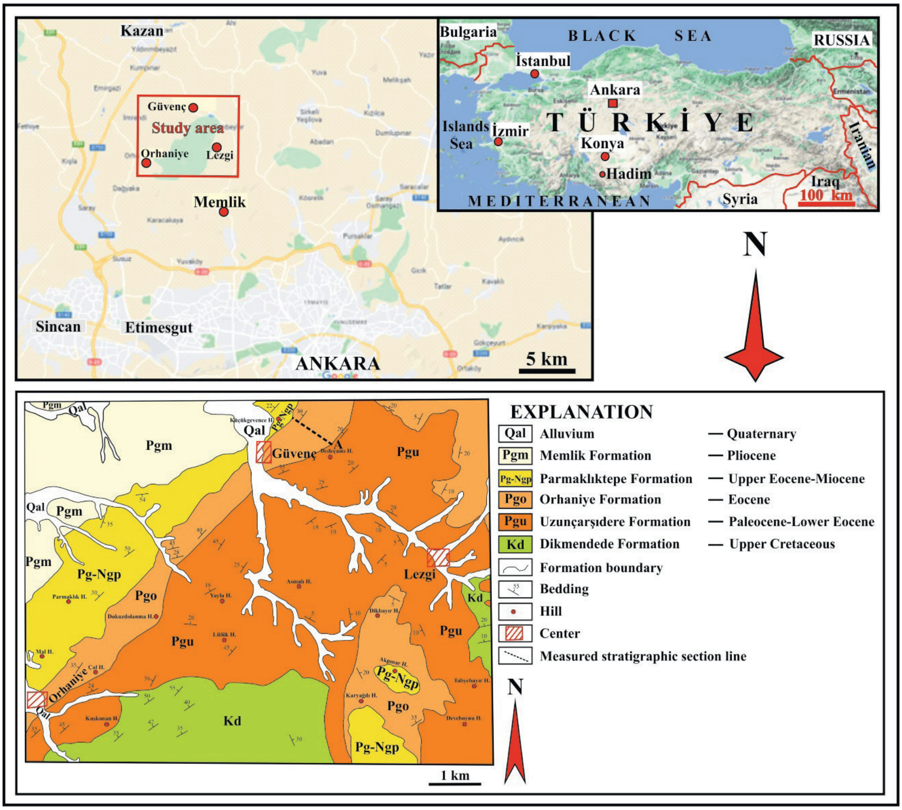

Figure 1. Location (GoogleMaps) and geological map of the study area (modified from Özkan and Ayaz, 2004)

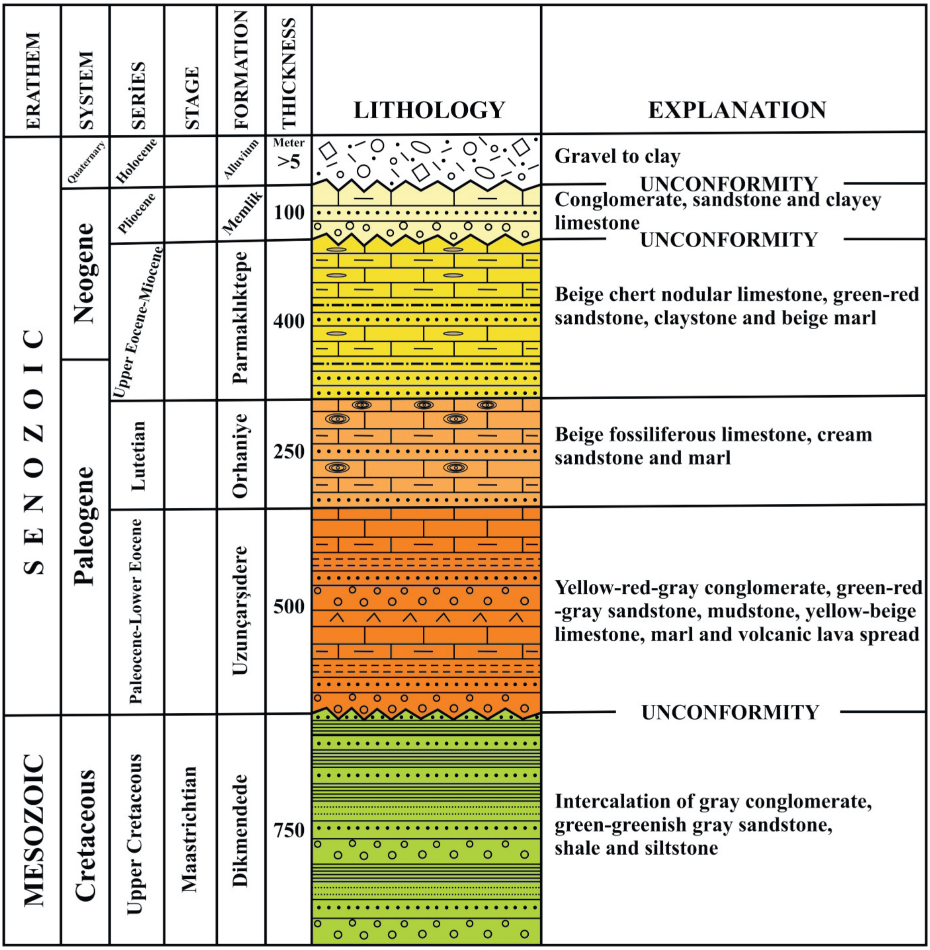

Figure 2. Stratigraphic column section of the study area (modified from Özkan and Ayaz, 2004)

A measured stratigraphic section was taken towards northwest from Dedeçamı Tepe, which is the best exposed part of the Orhaniye Formation (Figure 3). Orhaniye Formation includes sedimentary facies in which deposition takes place in shallow marine, lacustrine and braided fluvial environments (Figure 3). While the Orhaniye Formation exhibits a sterile condition in terms of sedimentary structure, it is rich in micro and macro fossils.

Sedimentary Characteristics of Orhaniye Formation

The Orhaniye Formation starts with green and/or cream-colored sandstone and mudstone with no fossils at the base and containing fossils upwards. After this section, which is 8-10 m thick, the unit continues with cream-beige colored limestones with abundant fossils (Figure 3).

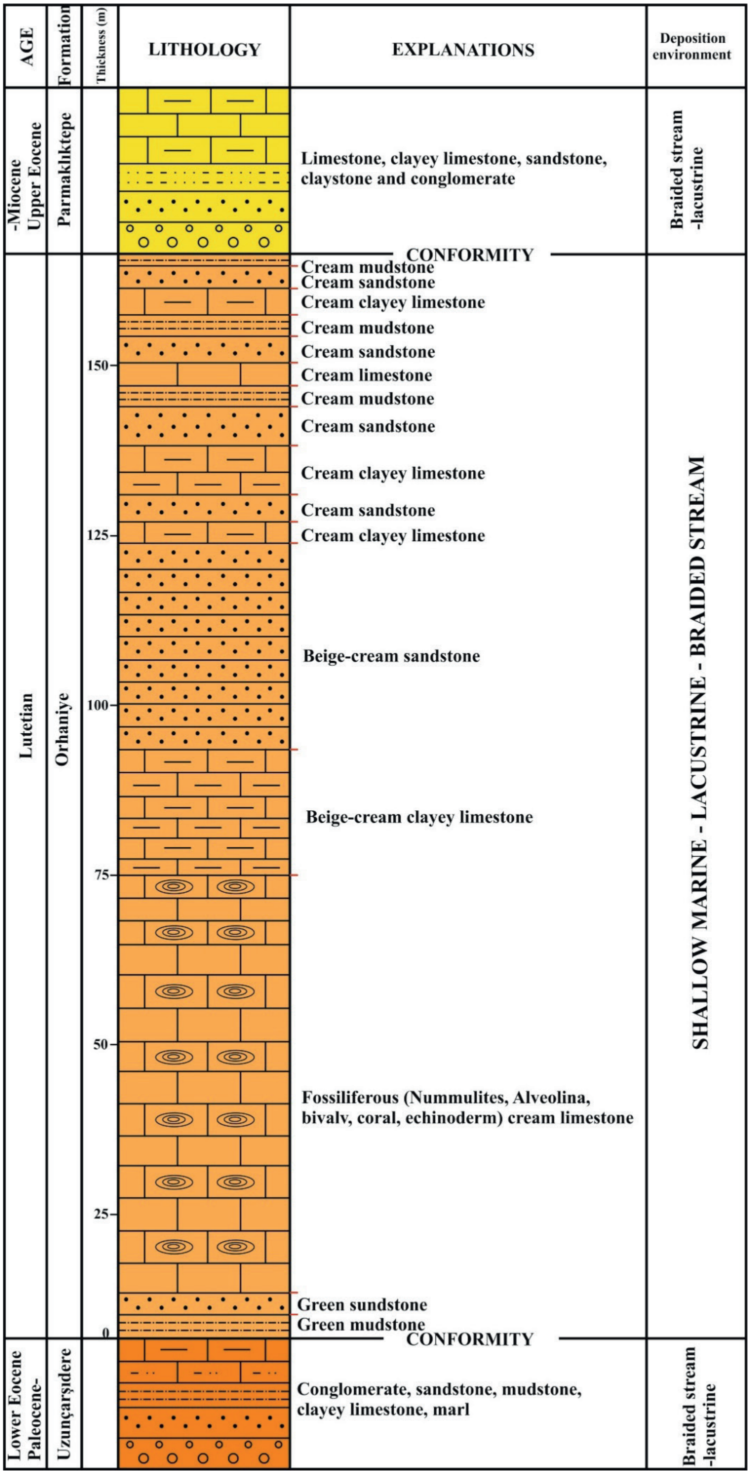

Figure 3. Orhaniye Formation type section (modified from Özkan and Ayaz, 2004)

These limestones contain abundant fossils such as *Nummulites* (Figure 4), coral, echinoderm (Figure 5), miliolid (Figure 6), *Alveolina* (Figure 7), *Textularia* (Figure 8), ostracod (Figure 9), and bivalve. In addition, fenestra structures (Figure 10) are also observed in the micritic matrix at some levels.

Figure 4. Nummulites sp. (black arrow) observed in the limestones of the Orhaniye Formation (southwest of Çal Hill) Scale (pencil length: 14 cm)

Figure 5. Echinodermata fossils (black arrows) were observed in the limestones of the Orhaniye Formation (Akkaya Ridge). Scale (pencil length: 14 cm)

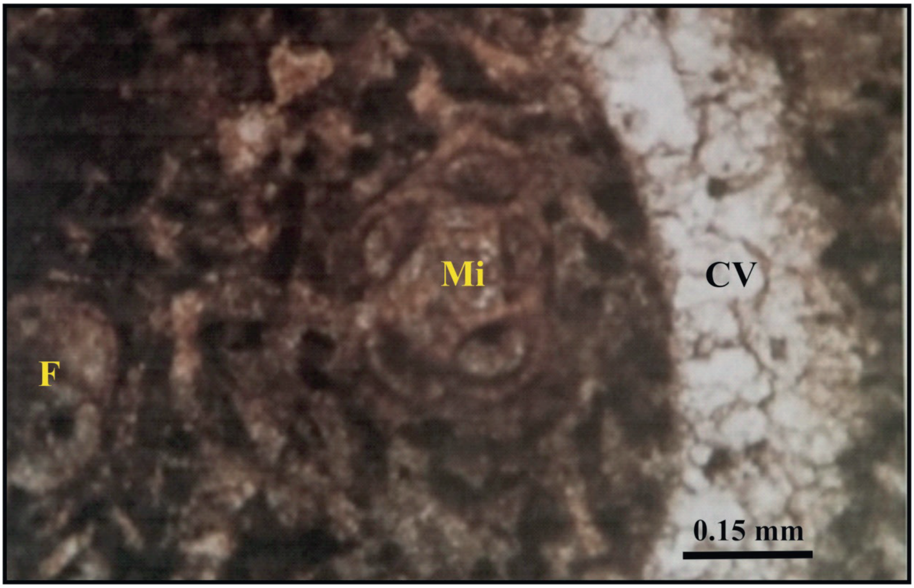

Figure 6. Miliolid (Mi), fossil (F), and calcitic vein (CV) observed in the limestones of the Orhaniye Formation (PPL)

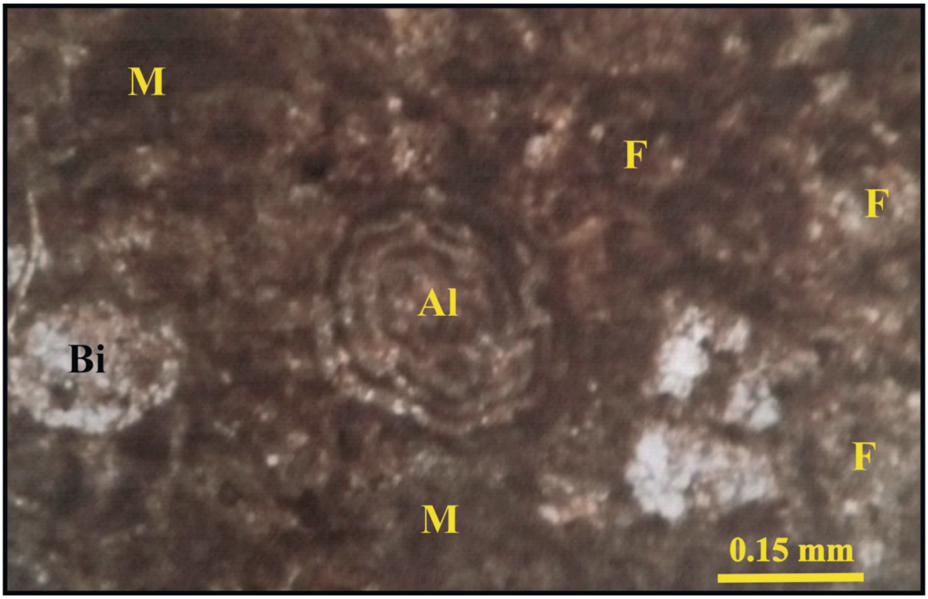

Figure 7. Alveolina sp., biomold (Bi), fossils (F), and micritic matrix (M) observed in (AI) the limestones of the Orhaniye Formation (PPL)

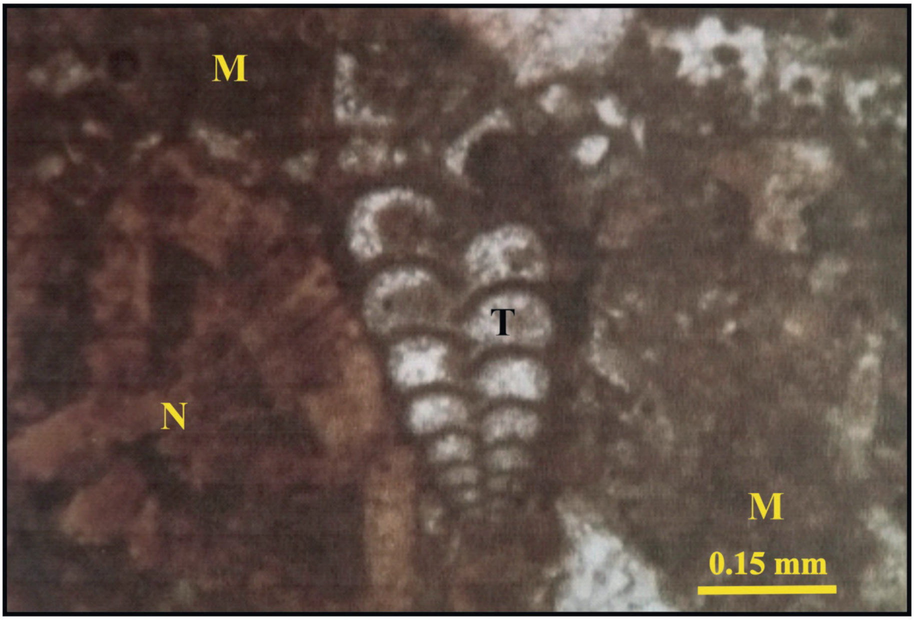

Figure 8. Nummulites sp. (N), Textularia sp. (T), and micritic matrix (M) were observed in the limestones of the Orhaniye Formation (PPL)

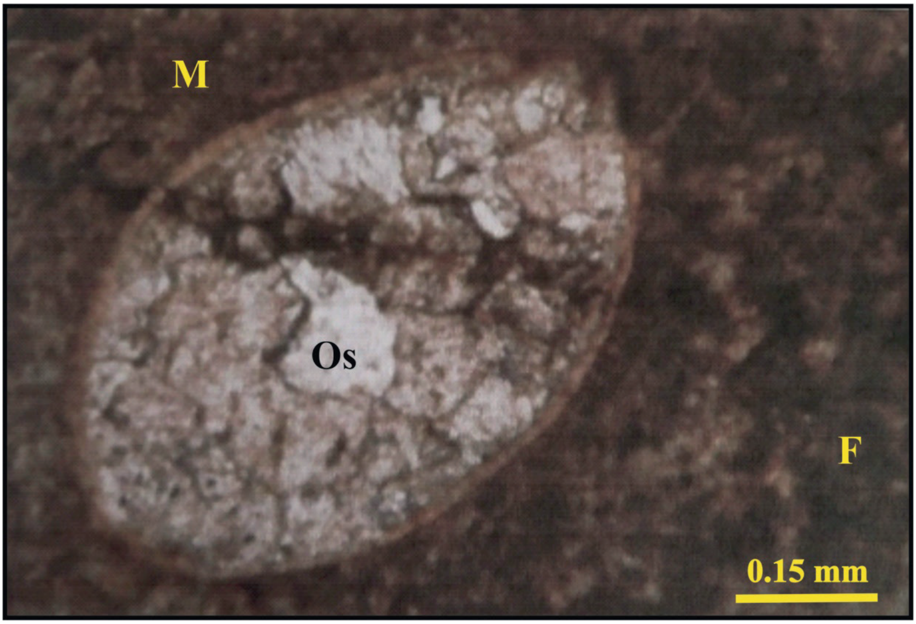

Figure 9. Ostrocod (Os), fossil (F) and micritic matrix (M) observed in the limestones of the Orhaniye Formation (PPL)

The Orhaniye Formation passes into beige-cream colored clayey limestones and beige-cream colored sandstones towards the top (Figure 3). The unit presents intercalation of cream colored clayey limestone, sandstone mudstone and ends with mudstone (Figure 3).

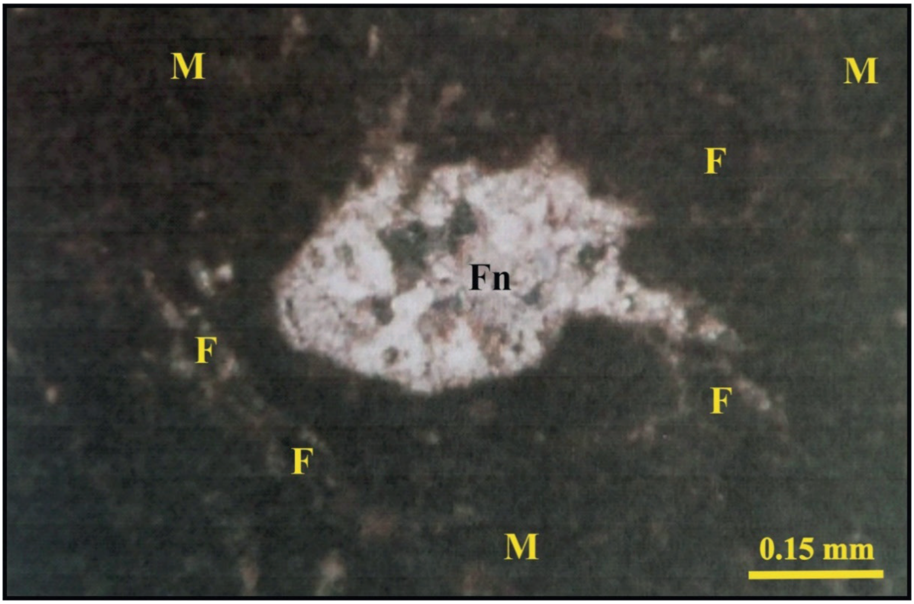

Figure 10. Fossil (F), fenestra (Fn), and micritic matrix (M) were observed in the limestones of the Orhaniye Formation. (XPL)

In the samples taken from the limestones of the Orhaniye Formation, 20-35% fossil, 2-8% pellet, 2-3% intraclast, 25-65% micritic matrix and 5-50% sparry calcite cement were determined (Figure 6-10). The fossils mostly consist of benthic foraminifers (Figure 6-8), and represent a shallow marine and lagoonal environment. The chambers of the fossils may be filled with micritic matrix or filled with sparry calcite cement (Figures 6-10). Substitution of amorphous iron cement is also observed in some fossils (Figures 6-8).

In some samples of the Orhaniye Formation limestones, it was observed that the micritic matrix was transformed into micro-sparite due to the neomorphism developed in the diagenetic process. Again, in some samples, the sparry calcite cement precipitation took place during the diagenetic process.

In the petrographic examination of the limestones of the Orhaniye Formation, the rock nomenclature was determined to be wackestone and packstone according to the Dunham (1962) classification.

Orhaniye Formation is overlain by the Paleocene-Early Eocene aged Uzunçarşıdere Formation with a conformable contact (Figure 11) at its lower boundary, while it passes with a conformable contact with the Late Eocene-Miocene aged Parmaklıtepe Formation at its upper boundary (Figures 2 and 3). The thickness of the Orhaniye Formation is 165 m compared to the measured stratigraphic section (type section) (Figure 3). In addition, Ocakoğlu (1998) stated the thickness of the Orhaniye Formation as 165 m in his study in the study area.

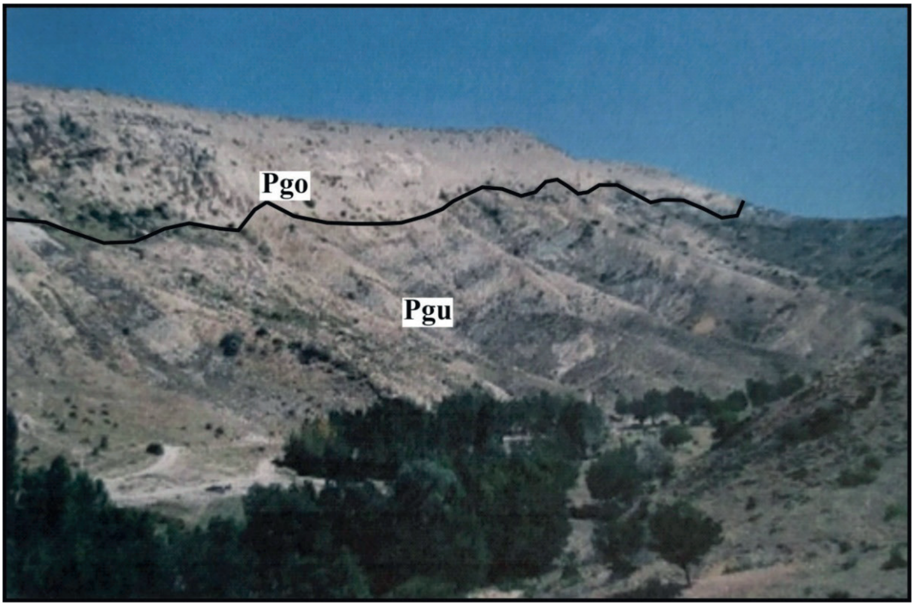

Figure 11. Boundary relationship of Uzunçarşıderee (Pgu), and Orhaniye (Pgo) formations (looking northeast from the northeast hillside of Kuşkonan Tepe)

Gökten et al. (1988) gave the Orhaniye Formation a Middle Eocene (Lutetian) age according to the benthic forminiferous fossils they collected from the unit in their study in and around the study area. Microfauna: *Nummulites laevigatus*, *Nummulites uranensis*, *Nummulites lehneri*, *Nummulites gizehensis*, *Nummulites millecaput*, *Nummulites ataricus*, *Nummulites perforatus*, *Nummulites brangniarti*, *Alveolina frumentiformis*, *Alveolina elliptica nuttalli*, *Alveolina* cf. *tenuis*, *Sphaerogypsina globulus*, *Eorupertia magna* (from Gökten et al., 1988). Macrofauna: *Echinolampas heberti*, *Schizoster* cf. *vidali*, *Brissopsis* cf. *vilplanae*, *Euspatangus subovatur*, *Euspatangus gibretensis*, *Ostrea* aff. *uncifera*, *Ostrea* (*Alectryonia*) aff. *ctotbeyi*, *Campanile giganteum*, *Velatesschimideli chemnita*, *Arca* (*Barbatia*) *insignis* (from Gökten et al., 1988).

Fossils such as *Nummulites* sp., *Alveolina* sp., *Textularia* sp., Miliolidae, Ostracoda, Echinodermata, Bivalvia and coral were compiled from the Orhaniye Formation by Özkan and Ayaz (2004) and assigned a Lutetian age to the unit. In this study, the unit was given a Lutetian age.

While the lithological and paleontological features of the Orhaniye Formation show the deposition in a shallow marine environment, they emphasize the deposition in the lacustrine environment and finally in the fluvial environment.

Acknowledgment

This study was supported by the project numbered 2003/024 by the Scientific Research Projects Coordinatorship of Selçuk University. The authors would like to thank Selçuk University Scientific Research Projects Coordinatorship.

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Chapter 5

DEEP FRYING AND PRE-TREATMENT APPLICATIONS FOR REDUCING OIL ABSORPTION

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1. Introduction

One of the first known commercial and domestic food preparation and cooking techniques, deep frying has a Mediterranean background. Before eating, many foods are heated to improve their appeal, flavor, and digestibility (Oke et al., 2018). People of all ages enjoy and consume fried foods because of their distinctive flavors, preferred colors, and crispy constructions (Ananney Obir et al., 2020). This is because meals that are deep-fried develop distinctive aromas and textural qualities that are not possible with other cooking methods. Because of this, engineering scientists and researchers as well as designers and manufacturers are very interested in deep frying (Tirado et al., 2015).

When frying, heat and mass are transferred simultaneously. This includes the movement of heat from the fried oil to the food products, the transport of moisture from the food products to the environment, and the absorption of oil from the food products. At the time of frying process, food is usually cooked in oil heated to 150-190 °C. In fried foods, many physicochemical changes occur, such as shrinkage, swelling, protein denaturation, browning, scab formation due to surface drying, and starch gelatinization in which starch granules swell. Macro- and micro-structural changes in products are the result of these physical and chemical changes (Oke et al., 2018).

The frying process is broken down into 4 phases:

- initial heating,
- boiling on the surface,
- rate reduction and
- bubble formation.

During frying, the oil moves to the food via the pores developed by the evaporation of the H_2O present in the food products's structure. As the frying process goes on, the food sample's surface becomes harder due to the development of a crust brought on by the rise in frying temperature, which slows down the mass transfer rate (Oladejo et al., 2018).

In general, frying in oil is a quick dehydration process that is impacted by numerous parameters, consisting of temperature, frying time, oil type, product size, and structure. It is primarily distinguished by three characteristics. These are that the product temperature (apart from the crust zone) typically does not surpass 100 °C, water-soluble chemicals are lost at a very low level, and cooking in a short amount of time are made possible by the high temperature (160–180 °C) (Dursun apar, 2014).

The conflict between drainage and absorption leads to the complicated and surface-oriented phenomena known as fat absorption into fried foods (Myers and Brannan, 2012). The mass transfer phenomena in the frying step includes the surface properties during and after frying, as well as the outflow of water and the entry of oil brought on by the transmission of heat energy to the product. Convection transfers heat from the oil to the food product's surface and then to its center when it is being fried. Due to the pressure applied by the H_2O, the water in the food complex travels through the food's tiny slits and causes the pores to open. The production of a crust on the food's surface is caused by the loss of water, which raises the surface temperature to a point where it approaches that of the frying oil. Excessive pressure during frying limits significant oil absorption, even though some oil can partially replace the water that is lost (Oke et al., 2018).

Ouchon et all. (2003) explained 3 distinct oil rates in fried potatoes depending on the different absorption mechanism and these fractions were:

- structural oil (fat absorbed at the time of frying process),
- oil absorbed from the product surface (oil absorbed into the food product at the time of cooling step after frying process) and
- surface oil of the food product (remaining oil on the external of the food material).

With this study, the researchers showed that since the absorption of oil and the separation of H_2O from the food product are not simultaneous during frying, there is a small amount of oil penetrating at the time of the frying step, and the majority of the oil is absorbed once and for all the process.

During frying, oil absorption occurs at different stages. Water is replaced by oil as a result of modification in the cellular form of the food material caused by frying process and voids created by the evaporation of H_2O. As the H_2O turns to steam during frying, it leaves the product and forms a spongy uniform network throughout the product. Most of the oil enters the food through these crevices that form during the first 20 seconds of frying (Moreira et al., 1999). At the time of frying step, part of the moisture content in the food material becomes steam, creating a pressure difference. Vapor escapes through the capillary spaces and channels of the cell structure. Fat adhering to the surface of food and capillary cavities is pushed out by the pressure difference. The steam generated during frying prevents oil from penetrating into the ingredients. The vacuum effect caused by condensation during cooling reduces the internal pressure of the food. This makes it easier for the oil to penetrate the food. Oil entrance deepness is about 1 mm (Saguy et al., 1997).

2. Effect of Deep Fried Products on Health

The increase in the sensitivity of consumers in developed countries to the interaction among food, nutrition and health reveals the necessity of limiting fat consumption, calories and cholesterol taken from fats (Dursun Çapar, 2014). Fats, which have an important place in human nutrition, are provided from plant and animal sources. Vegetable oils are easier and cheaper to produce than animal fats. At the same time, consumption of vegetable oils is healthier than animal fats. Therefore, vegetable oils are used more in the preparation of foods. In addition to being an excellent source of energy, edible oils are excellent solvents and carriers for fat-soluble vitamins which are A, D, E and K, as well as a source of essential fatty acids that the human body cannot synthesize. Diet (O'Brien, 2009). In particular, unsaturated fat intake is considered to be one of the key parameters involved in human health hazards (coronary heart disease, cancer, diabetes, hypertension, etc.) (Dursun Çapar, 2014). The expected benefits of oil can only be achieved by consuming the required amount of uncontaminated oil. The cis, trans, or conjugated form of fatty acids in the oil structure is of particular interest to consumers, as are structural features such as saturation, monounsaturation, and polyunsaturation. Certain illnesses can result from overconsumption of certain forms of oil (Dana and Saguy, 2001).

Frying prosess makes higher the total fat content and energy value of food products. Fried food materials generally contain about 1/3 of their total weight in fat for the most part (Myers & Brannan, 2012; Zeng et al., 2016). The negative effects of fried foods on health are attributed to excessive oil absorption, oil degradation and toxic chemicals produced during frying. For example, trans fatty acids increase the LDL (low-density lipoprotein) concentration and decrease HDL (high-density lipoprotein) concentration by having more negative effects on lipid levels in blood plasma than saturated fatty acids (Açar, 2011). In particular, excessive utilization of saturated fatty acids is identified as one of the main determinants that endanger human well-being and can lead to diseases such as coronary heart diseases, cancer, diabetes and hypertension (Dana and Saguy, 2001).

The high fat content in fried products has been a consideration for food businesses from an economic frame of reference and also for consumers from a health point of view. Due to these concerns, important studies are currently being conducted to make less the fat composition of fried food products, to increase their quality, and to investigate the related mechanisms (Aguilera and Gloria-Hernandez, 2000). Pre-treatment applications take an important place in these studies.

3. Pre-Treatment Applications to Reduce Oil Absorption

Pretreatments used in order to make less fat absorption and enhance the overall quality of fried food products fall into two main categories: traditional and innovative methods. Traditional methods are based on common and ancient methods of frying food. An example of this is: Hot air drying process (Moyan & Pedresc, 2006), boiling process (Taiow & Baiki, 2017), coating process (Chen et al., 2009), osmotic drying process (Krokiad et al., 2001) and freze drying process (Mait et al., 2012). On the other hand, these traditional pretreatment techniques have some disadvantage such as high energy utilization, long treatment times and low efficiency (Oladejo et al., 2018).

Innovative pretreatments, on the other hand, are technologies that have emerged and started to be used in recent years due to some of their advantages (environmentally friendly, fast, protection of nutrients, low energy use, high efficiency) (Awad et al., 2012). Examples of these methods are: superheated stream dying process (Van Lon et al., 2005), infrare technologies (Bigol et al., 2012), US application (Dehghanya et al., 2016), microwave process (Adedej et al., 2009) and pulsed electrical field application (Janozitz et al., 2011).

3.1. Traditional Methods

3.1.1. Hot Air Drying (Pre-Drying)

According to some reports, drying food with a hot air dryer before frying is a good strategy to lessen oil absorption. According to Oladejo et al. (2018), the drying temperature utilized in the food sector and laboratories to dry agricultural goods typically varies between 60 and 70 °C.

According to Krokid et al. (2001), longer drying times before frying caused the moisture and oil ratios of deep-fried french fries samples to decline. On the other hand, they claimed that the pre-drying procedure had unfavorable consequences, such as making fried potatoes more red and less yellow.

According to Martnez-Avil et al. (20010), pre-frying and post-frying drying of chicken nuggets reduced the fat content around 42% and 50%, subsequently, in comparison with the contro samples.

3.1.2. Boiling

Boiling refers to soaking the foodstuff in hot H_2O for a very short time fort he purpose of maintaining some quality specifications. At he time of boiling, gelatinization of starch takes place, which leads to some changes in the structure of the food product. Boiling has also been used in the food industry as a pre-treatment earlier than frying process to improve the quality of fried food products (Oladejo et al., 2018).

Pedrescih and Moyono (2005) compared cooked potato slices with uncooked (control) potato slices for oil absorption and texture when fried at 180 °C and found, unexpectedly, We found that the cooked samples absorbed more oil than the control samples. The researchers attributed the reason to surface wetting, but the only pretreatment, blanching and drying, was found to be less oily than the control at frying temperatures of 120, 150, and 180°C.

In a study, sweet potato slices, which were boiled for 10 minutes at 70 °C as a pre-treatment, were deep fried at 170 °C for 30 sec to 300 sec. According to the results, it was determined that boiled sweet potatoes showed lower porosity and volumetric change in comparsion with the control samples, and the boiling process caused a 50% degradation in the beginning firmness of the sweet potato samples. Researchers explained this situation with the disintegration, depolymerization and deterioration of cell wall pectin (Taiwo and Baik, 2007).

3.1.3. Coating

In order to minimize the oil and moisture content of fried dishes, coating is the technique of coating foodstuffs with solutions containing edible components (Oladejo et al., 2018).

Protein-based edible coatings were found to reduce the fat absorption of deep-fried foods more than hydrocolloids in a study using proteins from vegetable and animal sources to reduce the fat content of fried foods. However, some sources, such as soy, whey, egg white, and wheat protein, were found to reduce the fat absorption of fried foods. Their extensive use is reportedly limited due to allergenicity issues (Ananney-Obir et al., 2020).

The functional qualities of foodstuffs, such as viscosity, water holding capacity, and emulsification, are typically controlled and improved through the application of hydrocolloids. For the purpose of minimizing oil absorption at the time of deep frying application, various hydrocolloids, particularly polysaccharides, can be used as edible coatings (Martelli et al., 2008).

In the study by Lalam et al. (2013), samples of chicken wings were coated with methylcellulose before being cooked in heated oil at 175 and 190 °C for 30, 60, 120, and 240 seconds. At the conclusion of the investigation, it was shown that chicken wings coated with methylcellulose had lower fat contents than the control, although moisture loss was lower in the coated samples.

In a different investigation, coating solutions composing of around 1% carboxl methy cellulose (CMC) and 1% hydroxypropyl methyl cellulose (HPMC) were applied to fish nuggets before they were deep-fried. The results showed that when fried in a standard deep fat fryer and microwave fryer, nugets with 1% CMC and 1% HPMC had higher moisture and less oil compared to the control, and this was stated to be because of the gel form of CMC & HPMC (Chen et al., 2009).

3.1.4. Osmotic Dehydration

Osmotic dehydration is the process of removing both solutes and water from the osmotic solution that surrounds food. Due to its simplicity of usage, ability to preserve nutrients, and structural stability, it is frequently employed in the food sector to partially remove water from agricultural products. According to Oladejo et al. (2018), osmotic dehydration is also utilized to lower fat intake and enhance the quality features of fried dishes.

In the study by Krokida et al. (2001), pre-fried french fries were treated in 4 particular osmotic dispersions (sucrose, sodium chloride, maltodextirn 12 and maltodextrin 21) at the degrre of 170 °C for varying periods (0.3, 0.6, 1, 3, 5, 7, 10, 13 and 15 minutes). According to their findings, the samples that had undergone pretreatment with sucrose solution had the least amount of moisture and oil, followed by solutions containing NaCl, maltodextrin 21, and maltodextrin 12, respectively.

Bunger et al. (2003) observed a 22.2% reduction in the oil content of French fries treated with NaCl compared to the control after soaking the potato slices in a 3% NaCl solution for around 50 minutes and frying them at 180 °C for 6 minutes. At the same time, they discovered that the color was maintained and the hardness of the paotato samples exposed to NaCl increased.

3.1.5. Freezing Techniques

Commonly utilized freezing methods in the food business include freeze drying and freezing of foods. Both approaches seek to lessen the foods' initial moisture content. According to Novak et al. (2016), freezing is the process of turning H_2O molecules in food structures into ice crystals at low temperatures. The dimensions of the crystals relies on the freezing ratio (slow or quick freezing process). In contrast, freeze drying involves sublimating a food product at low pressure and temperature to remove water (Jiag et al., 2011).

Some research have looked into the viability of using freezing techniques as a pre-frying pre-treatment to enhance the quality of fried dishes. The foam and smoke issue that typically arises during industrial frying can be resolved by frying frozen food (Maity et al., 2012). According to Gamble and Rice's 2007 research, freeze-dried potato chips that are fried at 165 °C absorb more oil than chips with no treatment. This finding was further supported by the study of Kawas & Moreira (2001), who found that cooked freeze-dried tortila chips samples contained more oil, had a softer structure, and were less porous than the control. Because there are just a few tiny pores in the structure, pre-treating food by freeze-drying before frying results in low gelatinization of starch, which inhibits oil absorption during frying less.

3.2. Innovative Methods

3.2.1. Superheated Steam Drying

An innovative technology has lately been used in the food business to dry agricultural products is called as superheated steam drying. By heating food products and eliminating the evaporating H_2O from the food materials, it serves as a drying tool. Pressure, steam temperature, and flow can all be changed to alter the ultimate moisture content (Oladejo et al., 2018). VanLoon et al. (2005) looked into the viability of pre-treating foods before frying by employing superheated drying. In comparison to air drying, they claimed that superheated steam drying produced products with a reasonable level of quality.

Zielinska et al. (2015) looked into how the quality of potato chips was affected by superheated drying before frying. According to their findings, superheated steam drying reduced the oil content of potato chips by 15–27%, and the prepared chips' red and yellow hues were lighter. Primo-Martn and Van Deventer (2011) carried out a trial that was comparable to this one, in which the cookie dough was dried in hot steam before being fried for three minutes at 180 °C. According to reports, applying superheated steam drying application as a pretreatment after frying process causes the total oil content to be lower. This is because the crust's surface is extremely rough due to starch gelatinization and the existence of an amylose film, which lowers oil permeability.

3.2.2. Infrared Technology

In a catalytic infrared emitter driven by natural gas and/or propene, thermal radiant radiation known as infrared is created by a catalytic interaction with a built-in catalyst pad. Agricultural goods are dried, peeled, inactivated, and roasted using infrared technologies in the food sector. In addition to these uses, several researchers have recently looked into the viability of utilizing infrared as a pre-treatment prior to frying to enhance the quality of fried foods (Oladejo et al., 2018).

Potato slices were pretreated by Bingol et al. (2012) using a pilot catalytic infrared system with an infrared intensity of 11.080 W/m2. The potato strips were heated from the bottom and the top for 30, 60, 90, 120, 150, and 180 sec at the time of the pre-treatment. They were then fried at 146, 160, and 174 °C for 1, 3, 5, and 7 minutes, respectively. It was noted that the samples subjected to infrared treatment at frying temperatures of 146, 160, and 174 °C contained 37.5%, 32%, and 30% less oil, respectively, than the control samples.

According to reports, another contributing reason to this is the development of an elastic white crust, which slows the spread of the oil.

In a different investigation, Bingol et al. (2014) examined the impact of pretreatment methods for french fries—water blanching and infrared blanching—on the final product quality. They claimed that the infrared-pretreated French fries had less moisture and oil than their conventional counterparts that had been boiled in water.

3.2.3. Microwave Technology

One of the innovative techniques for pre-processing food before frying to enhance the quality of fried foods is the use of microwave technology. Through the use of microwave technology, food absorbs energy, creating a pressure gradient that causes the formation of internal heat and, in turn, an increase in moisture loss within the meal (Barutcu et al., 2009). There are two basic ways that microwave technology can be used to fry food in both industrial settings and lab settings. The food material is either microwaved for a while before deep-frying, or the frying process either occurs immediately in the middle of the microwave equipment, where the heat source inconsequence of frying is produced by the microwave power (Oladejo et al., 2018).

According to Chenn et al. (2009), microwave frying expedites and enhances the frying process. Su et al. (2016) examined the use of microwave assisted vacuum frying (MVF) application in order to lower the fat content and enhance the features of potato chips samples in a recent study. When cooked in MVF at 12, 16, and 20 W/g microwave power densities, frying temperatures of 100, 110, and 120 °C, and vacuum degrees of 0.065, 0.075, and 0.085 MPa, potato chips exhibit less color change, preserved cell integrity, and decreased fat content while evaporating moisture more quickly and developing a crispier texture.

The largest fat reduction was seen in chicken wings cooked at 6.7 W/g and fried at 170 °C, according to Adedeji et al.'s (2009) investigation of the kinetics of mass transfer in microwaved and deep-fried chicken wings samples.

Ngadi et al. (2009) investigated how deep-frying of chicken nuggets affected mass transfer after microwave pretreatment. The coated chicken wings were microwaved for one to two minutes before being fried at 160 °C for a period of 0 to 300 seconds. After being fried for 300 seconds, it was discovered that the fat content of chicken wings that had been microwaved for 1 or 2 minutes had decreased by 26.22% and 33.51%, respectively, compared to the control.

3.2.4. Pulsed Electric Field

The introduction of a high voltage electric field for a brief period of time (microsecond to millisecond) to a sample positioned between electrodes is known as a pulsed electric field (PEF). In the food sector, it is frequently used for microbial inactivation, freezing, and drying. The quality of fried foods has recently been improved by using PEF as a pre-frying pretreatment (Oladejo et al., 2018).

Cell wall permeability, tissue softening, and pore creation are all benefits of pulsed electric field (Ngadi et al., 2003). Igant et al. (2015) examined the impact of pre-frying PEF pre-treatment on the properties of French fries samples. In either a 2.50 kV/cm electric field for 810 pulses or a 0.75 kV/cm electric field for 9000 pulses, potato cubes were subjected to PEF treatments. According to reports, fried potato slices prepared with PEF had less fat than the control group.

Whole sweet potato tubers were given PEF treatments with voltages between 0.3 and 1.2 kV/cm. According to reports, samples pretreated at 1.2 kV/cm and cooked at 190 °C had an 18% lower oil ratio rather than sweet potato samples with no treatment. According to Liu et al. (2017), their findings can be applied to the food related sectors in order to arrange the PEF application parameters of solid meals prior to frying.

3.2.5. Ultrasound Technology

Due to its many benefits, including convenience, cheap cost, quick processing time, little material consumption, and preservation of the nutritional content of processed foods, ultrasound is a developing technology employed in many fields of food processing, preservation, and safety (Oladejo et al., 2018). In the process of processing food, cavitations produced by ultrasound, which consists of sound waves of 20 kHz and above, cause mechanical, physical, and chemical changes such dehydration, mixing, shearing, hydrolysis, extraction, and emulsification (Awad et al., 2012).

Depending on the sound power, sound intensity, or sound energy density used, there are low energy and high energy ultrasound applications used in the food processing, analysis, and quality control industries. Low energy (low power, low intensity) ultrasound is used for non-invasive analysis, monitoring, and quality and safety testing of various food items throughout processing and storage. It has frequencies more than 100 kHz at densities below 1 W/cm2. Ultrasound that is high-energy (high-power, high-intensity) employs intensities greater than 1 W/cm2 between 20 and 500 kHz. According to Awad et al. (2012), these damaging actions alter the physical, mechanical, chemical, or biological characteristics of food.

Applications for high power ultrasonic waves involve the use of ultrasonic energy to alter food products permanently. A promising application of ultrasonic waves is the use of high power ultrasound in the food industry, which will have several significant benefits. Power ultrasound, for instance, enhances heat and mass transport phenomena during the dehydration process. The sponge effect, which is a quick succession of alternating compressions and expansions caused by ultrasonic waves, is comparable to the repetitive squeezing and unsqueezing of a sponge. The forces used in this technique have the ability to form microscopic channels that aid in moisture elimination. Additionally, ultrasound causes cavitation, which might aid in releasing moisture that is tightly bound. In porous foods like fruits, the sponge effect brought on by the application of ultrasound results in the development of microscopic channels (Dehghannya et al., 2016).

3.2.5.1. Effect Mechanism of Ultrasound

When travelling through any physical medium, ultrasonic waves, like other sound waves, create compression and expansion series in the material. When the amplitude of the waves surpasses a particular threshold during their circulation in the liquid phase, they create micrometer-sized bubbles in the medium. When these bubbles have absorbed all the energy they can from their surroundings to a certain point, they burst and sink inward. This occurrence is known as cavitation. Gas bubbles are created in the liquid and continue to expand as a result of the energy they absorb. This event, which occurs within 400 s, is regarded as the most crucial one to comprehend in order to comprehend how ultrasound is formed (Tao and Sun, 2015).

According to estimates, the pressure and temperature of the bubbles during the implosion may both be 1000 atm and 5000 oK. In relation to the amount of the liquid, the size of the bubbles is extremely small. As a result, under ambient conditions, the heat generated by the bubbles dissipates swiftly and undetectably (Chemat et al., 2011).

Transient and steady cavitation are the two types of cavitation. The bubbles in stable cavitation form with each ultrasonic cycle and continue to form without collapsing because they don't get big enough to burst and fall inwards. Low acoustic pressures are where these bubbles form. The bubbles expand quickly at high acoustic pressure, but when they reach a particular size, they burst and collapse inward. Transient cavitation is the name given to this phenomena. High temperatures (up to around 5000 °K) and high pressures (up to about 100 MP = 1000 atm) are created when these bubbles suddenly rupture (Tao and Sun, 2015).

3.2.5.2. Application of Ultrasound Technology in Fried Foods

Numerous studies have found that using ultrasound to prepare different food products is an effective method. For instance, the meat industry has used the ultrasound technique as an innovative technology to speed up the curing process, enhance the rheological and structural characteristics of protein substances, enhance the structural qualities of red meat, and increase its ability to retain water (Kang et al., 2016, 2017; Wang et al., 2017). However, researches on possible uses of ultrasonic technology to lower fat absorption or enhance product quality in deep-fried foods is scarce. The ultrasound technique was the subject of some of these research, while others concentrated on the ultrasonic technique when it was integrated with other technologies.

Zhang et al. (2021) investigated how the qualities and oil absorptions of potato chips were affected by US preparation. Before deep-frying the potatoes, they pre-treated them with ultrasound at 120, 240, 360, 480, and 600 W intensities for 30, 60, and 90 minutes. In addition to causing a 27.66% recution in whole oil composition and significant reductions in surface oil penetration into the potato chips, the researchers found that ultrasound pretreatment applied at 360 W intensity for 60 minutes changed cell viability, which in turn caused macro-level changes in fat distribution. Additionally, they claimed that increased ultrasonic intensity caused greater cell destruction at the potato chip edge, increasing oil absorption there while also disrupting cell structure, which altered the distribution of oil at the microscopic level.

It is uncertain whether onication would be successful in lowering oil uptake at the time of frying process, according to Karizaki et al. (2013), because ultrasound forms microchannels inside the structure that can increase oil absorption. In light of this, the researchers assessed a number of quality factors, including the product's moisture ratio, oil absorption, colour, texture, and microstructure, to determine how ultrasound-assisted osmotic dehydration pretreatment affected the features of deep-fried potato samples. In the experiment, potato slices were supposed to sonication at a frequency of 20 kHz for 30 minutes in a dispersion of 15% Na chloride and 50% sugar before being fried at the degree of 170 °C for 2, 4, and 6 minutes. According to the study, compared to the control, potato strips prepped with ultrasound assisted osmotic dehydration demonstrated a 12.5% decrease in fat absorption. Additionally, they noticed that while the cell structure was more severely destroyed in the pretreatment samples in comparison with the control samples, the colour and structure of the potato samples were better.

Dehghannya et al. (2016) examined in a different study how sonication assisted air drying pretreatment affected the amount of fat in French fries. A 28 and 40 kHz ultrasound water bath was used for the pretreatments, along with drying pretreatments at 80 °C for 8 and 15 minutes before frying at 150, 170, and 190 °C. The pre-treated samples had less oil than the control sample, according to the researchers.

The effectiveness of ultrasound-assisted pretreatment to reduce the moisture ratio and oil uptake of sweet potatoes at the time of deep frying process was examined by Olodejo et al. (2017). Using sunflower oil at 130, 150, and 170 °C for 2, 4, 6, 8, and 10 minutes, potato samples were processed before being fried in ultrasonic, non-ultrasound, and ultrasound assisted osmotic drying water with 300 W power and 28 kHz frequency. The samples that underwent ultrasound assisted osmotic dehydration and non-ultrasound osmotic dehydration had the lowest moisture content, and the samples that underwent ultrasound pretreatment had the lowest oil absorption (65.11% at 150 °C and 71.47% at 170 °C).

The oil content of potato chips' samples that were both pretreated with convective air drying and pretreated with convective air drying combined with ultrasound decreased, according to the study that looked at the influences of convective air drying process and combined convective air drying pretreatments with ultrasound on the features and oil absorption of potato chips. The ultrasound-pretreated chips showed more pores and cracks. In potato chips, uneven cell deformation and loss of cell structure were less noticeable after drying. With convective air drying and convective air drying pretreatments combined with ultrasound, the hardness of potato chips increased as drying time was extended (Zhang and Fan, 2021).

According to Su et al. (2018), compared to microwave-assisted vacuum frying (MVF), ultrasonic microwave-assisted vacuum frying (USMVF) offers a lower frying temperature, greatly speeds up the dehydration step, and reduces drying period. The lipid uptake of french fries was decreased by ultrasonic application in MVF under low frying temperature settings. The fried potato chips' color and texture qualities (crispness) have both significantly enhanced. Compared to the MVF application, less energy was used in the USMVF application. Because USMVF application was carried out at a lower frying temperature, ultrasound had a higher impact on moisture evaporation ratio and quality properties of food product. With the help of USMVF samples, the effects of ultrasound might be explained by a more porous microstructure. This demonstrates that high quality fried food production efficiency may be achieved using the ultrasonic microwave assisted vacuum frying process.

The quality of sweet potato chips samples that had been microwave aided vacuum fried (MVF) and prepared with ultrasound was examined by Qiu et al. (2018). The pre-treated potato chips samples were subsequently fried with MVF. In the study, fresh sweet potato slices were pretreated at 150, 300, and 450 W ultrasound power for 20 minutes and at 300 W ultrasound power for 10, 20, and 30 minutes. It was discovered that raising the ultrasound pretreatment power and extending the processing period resulted in a decrease in the moisture ratio and oil absorption of fried sweet potato chips samples. The texture of fried sweet potato chips was made crispier by using higher ultrasonic power and longer processing times, but the colour and cell integrity of the fried potato chips samples suffered as a result.

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Chapter 6

MARKOV CHAINS FOR INDUSTRIAL ENGINEERING PURPOSES

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1 Introduction

Markov chains can be used to analyze industrial engineering processes. They enable us to forecast the long-term behavior of complex systems with multiple variables. We can simulate various scenarios and optimize our processes for maximum efficacy by using probability distributions to describe state transitions (Chen and Hu, 2016). Markov chains can also assist the user in identifying manufacturing line bottlenecks and opportunities for improvement. We can use Markov chains to make informed decisions that increase productivity and profitability if we have the right data and analysis. It is important to note, however, that Markov chains are only as accurate as the data they are fed. Precise measurements and thorough analysis are required for the development of trustworthy models that can make meaningful predictions about real-world systems. Markov chains can help industrial engineers improve their processes and maintain a competitive advantage (Doshi and Bard, 1997). This data can be used to improve production planning, inventory management, and quality control decisions. A Markov chain, for example, can be used to simulate the flow of customers through a store or the movement of goods along a supply chain. Engineers can optimize processes and reduce waste by analyzing the probabilities of various outcomes (Wang and Song, 2014). Markov chains can forecast future behavior based on past patterns, allowing businesses to forecast demand and adjust production accordingly. Markov chains can be used to identify bottlenecks in a system and recommend ways to improve efficiency (Sadeghi and Sadeghi, 2011). The use of Markov chains in industrial engineering has transformed how businesses approach problem solving and decision making. Engineers can make more informed decisions that lead to increased productivity and profitability by leveraging the power of probability theory (Zang and Wang, 2013).

Production, inventory management, and quality control are crucial to the success of a business. Reducing expenses, boosting customer satisfaction, and gaining a competitive advantage all necessitate an effective production process and inventory management. Markov chains are an analysis technique used in production and inventory management. Markov chains, a mathematical structure utilized in the analysis of random processes, are based on the premise that a system's future state is determined solely by its current state and that previous states have no effect (Liu, Xu, 2018). This is referred to as the Markov property, or lack of memory. This method can be used to model machine states (up, down, and in maintenance) in a production line, for instance. Markov transition models are statistical techniques for simulating the probabilities of state transitions over time (Feng and Chen, 2017). These models assume that future states are determined solely by the current state, ignoring the effects of previous states. Models of Markov transitions have found widespread use in numerous disciplines, including finance, economics, and engineering. In finance, they are used to model stock prices and predict market trends (Zang and Wang, 2020). In economics, they are used to predict economic growth and analyze consumer behavior. Engineering uses them to optimize production processes and enhance product quality. Models of Markov transitions have a wide range of applications because they are an effective method for comprehending complex systems with uncertain outcomes (Wang and Li, 2019). Markov transition models have been utilized in the healthcare industry to predict disease progression and assess treatment efficacy. In transportation, they have been used to model traffic flow and optimize transportation systems (Zhao and He, 2021). Also, Markov transition models have been used to analyze the impact of various environmental factors on climate change. In sports analytics, they have also been used to predict player performance and team outcomes.

Markov transition models are a useful tool for analyzing complex systems with uncertain outcomes, and they have been implemented in numerous disciplines ranging from finance and economics to climate science and healthcare. One of the primary benefits of Markov transition models is their simplicity. Assuming that future states depend solely on the current state, it is simple to construct and analyze these models using elementary probability theory. Consequently, they can be utilized by a variety of users with varying degrees of statistical expertise. Markov transition models have limitations, however. In actuality, it is not always the case that they assume the underlying system is stationary over time. Moreover, these models may not account for all relevant factors that influence state transitions, resulting in a lack of accuracy. Analyzing the business cycle dynamics of Turkey's manufacturing industry components using Markov transition models can aid in examining the transition probabilities between various economic states in the manufacturing sector. This analysis can provide insights into the cyclical behavior of the industry and help identify potential improvement areas. Understanding the patterns of state transitions allows policymakers and industry leaders to make informed decisions regarding resource allocation, investment strategies, and risk management. Numerous industries, including finance, healthcare, and transportation, have utilized Markov transition models with great success. In addition to analyzing state transitions, these models can be used to predict future states based on present conditions. This predictive ability is particularly useful in industries with high levels of uncertainty or volatility. In general, Markov transition models are an efficient method for analyzing complex systems and identifying growth opportunities.

2 Markov Chains in Production and Inventory Control

Markov chains are a type of stochastic process used to model systems in which the future state is solely determined by the current state and is independent of all previous states. This makes Markov chains ideal for modeling production and inventory control systems in which product demand is typically random and can only be predicted based on current inventory levels.

There are two types of Markov chains in production and inventory control: finite Markov chains and continuous-time Markov chains. When the number of possible states is finite, such as when inventory quantities are limited, finite Markov chains are utilized. Continuous-time Markov chains are utilized when the number of possible states is infinite, such as when the demand for a product can be any positive number.

Identifying the system's states is the first step in using a Markov chain to model a production and inventory control system. The system specifies the possible values for the inventory level. For instance, a system with a maximum inventory of 100 items may have states ranging from 0 to 100. Once the states have been identified, the probabilities of their transitions must be computed. These probabilities represent the likelihood of a state transition occurring within a given time frame. Transition probabilities can be estimated using historical data or expert knowledge of the system. After calculating the transition probabilities, they can be used to calculate a variety of performance metrics, including the expected inventory level, stockout probability, and order fulfillment rate. These metrics can help managers make informed decisions regarding inventory control policies, including reorder points and order quantities. In addition to production and inventory control systems, Markov chains are utilized in a variety of other fields, such as finance, healthcare, and telecommunications. They can be used to model stock prices or patient health states over time, for example.

The next step involves calculating the transition probabilities. The transition probabilities are the probabilities of changing states. For instance, if the current inventory level is 50 and the product demand is 10, the probability of transitioning to a state in which the inventory level is 40 is 50%.

After identifying the states and transition probabilities, the Markov chain can be used to calculate the probability of a particular inventory level at a given time. This information can then be used to determine production and inventory levels.

A company, for instance, could use a Markov chain to determine the optimal production quantity. Using the probability of the inventory level falling below the reorder point at a given time, the company could calculate the optimal production quantity that minimizes the cost of lost sales and holding inventory.

Markov chains are a highly effective modeling technique for a wide variety of production and inventory control systems. Using Markov chains to make more informed decisions regarding production and inventory levels can increase a company's profitability.

Here are some additional details regarding the application of Markov chains in manufacturing and inventory control:

- When the number of possible states is limited, it is common to employ finite Markov chains. This facilitates comprehension and analysis. Modeling a wide variety of production and inventory control systems, including single-item, multi-item, and backordered systems, with finite Markov chains.

- Markov chains with time that is continuous: When there are an infinite number of possible states, continuous-time Markov chains are typically employed. Consequently, they are harder to understand and analyze than finite Markov chains. On the other hand, continuous-time Markov chains can be used to model more complicated production and inventory control systems, such as those with stochastic demand and variable production costs.

Here are some production and inventory control applications of Markov chains:

- In a study published in the journal "Production and Operations Management," researchers modeled the inventory system of a manufacturer using a Markov chain. The researchers discovered that the Markov chain model accurately predicted inventory levels and could be used to make more informed decisions regarding production and inventory.

- In a study published in "Decision Sciences," researchers employed a Markov chain to model the inventory system of a retail store. The researchers discovered that the Markov chain model accurately predicted inventory levels and could be used to make more informed decisions regarding production and inventory.

Overall, Markov chains are an effective modeling technique for a wide variety of production and inventory control systems. Using Markov chains to make more informed decisions regarding production and inventory levels can increase a company's profitability.

3 Use of Markov Chains in Manufacturing Processes

Markov chains are a powerful tool for modeling a wide range of systems, including manufacturing processes. A number of factors, such as the quantity of materials on hand, the number of machines in use, and the number of finished products, can describe the state of a manufacturing process. The current state of the system and the transition probabilities—the likelihood that it will change from one state to another—determine its future state.

Markov chains can simulate a variety of manufacturing processes, including:

- In an industrial setting, Markov chains can be used to schedule machines. The objective is to reduce make-up time, or the total time necessary to complete all of the tasks.

- Markov chains can be used to manage inventories of both raw materials and finished goods. The objective is to keep inventory costs as low as possible while ensuring that there is always sufficient inventory to meet demand.

- Markov chains can be utilized for controlling product quality. The objective is to reduce the number of defects while ensuring that the products satisfy customer demands.

Utilizing Markov chains in manufacturing offers a number of benefits. These benefits include:

- Markov chains can be used to make better decisions regarding production, inventory, and quality control. This may lead to increased productivity and profitability.

- Risk reduction: Markov chains can be used to reduce the risk of disruptions in the manufacturing process. This can be achieved by identifying potential issues and implementing preventative measures.

- Changes in the manufacturing environment, such as changes in demand or resource availability, can be modeled using Markov chains. This can help manufacturers remain competitive while adapting to changing conditions.

Utilizing Markov chains in manufacturing poses numerous obstacles. Among these challenges are:

- For Markov chains to estimate transition probabilities, historical data are required. This information may not be accessible or may be difficult to acquire.

- As the number of states and transitions increases, Markov chains can become exceedingly complex models. This may make the model challenging to comprehend and analyze.

- Simulation of Markov chains can be computationally complex. This can make it challenging to model real-world systems using Markov chains.

Markov chains are an effective modeling tool for a wide variety of manufacturing processes. However, the use of Markov chains in manufacturing presents a number of obstacles, such as data requirements, model complexity, and computational complexity. Despite these obstacles, Markov chains can be a useful tool in manufacturing for enhancing decision-making, decreasing risk, and enhancing flexibility.

3.1 Modeling Transitions Between Workstations

In a manufacturing process, workstations are the physical locations where work is performed on a product. Material handling systems like conveyors, robots, and forklifts connect workstations. The use of Markov chains has been explored in multiple studies to improve manufacturing processes, including the modeling of transitions between workstations. Workstations are important physical locations where work is performed on a product, and material handling systems connect these workstations. The movement of products between workstations is a transition.

In manufacturing, transition modeling between workstations is a crucial issue. The purpose of this modeling is to comprehend how product movement between workstations affects the overall performance of the manufacturing process.

Multiple factors can affect the flow of products between workstations. These elements include the following:

- The number of workstations utilized in the production process
- The configuration of the workstation
- Capacity of material handling systems
- Individual workstation processing times
- The product's high demand
- Modeling Methodologies

Modeling transitions between workstations can be accomplished in a number of ways. Among these methodologies are:

- Analytical Models: Using mathematical equations, analytical models depict the movement of products between workstations. Typically, analytical models are utilized for small-scale production processes.

- Simulation Models: Using computer software, simulation models represent the movement of products between workstations. Typically, simulation models are used for large-scale manufacturing processes.

- Analytical Models

These assumptions form the basis for analytical models:

- There are a limited number of available workstations.
- The layout of the workstations is predetermined.
- The capacity of material handling systems is infinite.
- The processing times at each workstation are constant.

- The demand for the product is known.

Using analytical models, the following may be determined:

- The average time required for a product to complete the manufacturing process
- The average number of products in the manufacturing process at any given time
- The likelihood that a product will experience manufacturing delays
- Simulation Models

Simulation models are free of all assumptions. Consequently, they are more flexible than analytical models but also more intricate. Simulation models can be used to calculate the same things as analytical models, in addition to the following:

- The influence of modifications to the workstation layout
- The impact of modifications to material handling system capacity
- The effect of processing time varies per workstation.
- The effect of fluctuations in product demand

In manufacturing, transition modeling between workstations is a crucial issue. Modeling transitions between workstations can be accomplished in a number of ways. The chosen approach depends on the scale of the manufacturing process and the difficulty of the problem.

Here are some additional details regarding the various modeling techniques:

- Typically, analytical models are utilized in small-scale manufacturing processes. They are simple to create and employ, but they can only solve simple problems.
- Simulational models Frequently, simulation models are utilized in large-scale manufacturing processes. They are more complex than analytical models but can model more intricate problems.

Here are some examples of how transitions between modeling workstations have been utilized in manufacturing:

- Using a simulation model, a business analyzed the effects of reorganizing its manufacturing layout. According to the simulation model, the new layout would reduce the average manufacturing process time for a product by 10%.
- Using a simulation model, a business investigated the effect of changes to the capacity of its material handling system. The simulation model

indicates that the new capacity would increase the manufacturing process' output by 20%.

- Using a simulation model, a company analyzed the impact of changes to processing times at their workstations. According to the simulation model, the new processing times would reduce product defects by 50 percent.

Modeling transitions between workstations is an effective technique for enhancing the performance of manufacturing processes.

3.2 Use of Markov Chains for Prediction of Production Time

In manufacturing, production time is the time it takes to produce a product. It is important to be able to estimate production time accurately in order to meet customer demand and to avoid production delays.

There are a number of factors that can affect production time. These factors include:

- The complexity of the product
- The number of steps involved in the manufacturing process
- The availability of resources
- The efficiency of the manufacturing process

There are a number of methods that can be used to estimate production time. These methods include:

- Historical data: Historical data can be used to estimate production time by analyzing the time it took to produce similar products in the past.

- Expert judgment: Expert judgment can be used to estimate production time by asking experts in the manufacturing process to estimate the time it will take to produce a product.

- Simulation: Simulation can be used to estimate production time by creating a computer model of the manufacturing process and running the model to see how long it takes to produce a product.

The best method for estimating production time depends on the specific situation. Historical data is often the most accurate method, but it may not be available for new products or for products that are produced infrequently. Expert judgment can be used when historical data is not available, but it may not be as accurate as historical data. Simulation can be used when historical data and expert judgment are not available, but it can be more complex and time-consuming to use. Estimating production time is an important part of manufacturing. There are a number of factors that can affect production time, and there are a number of methods that can be used to estimate production time. The best method for estimating production time depends on the specific situation.

Here are some additional details about the different methods for estimating production time:

- Historical data: Historical data can be used to estimate production time by analyzing the time it took to produce similar products in the past. This method is most accurate when the products are similar in complexity and when the manufacturing process has not changed significantly since the products were last produced.

- Expert judgment: Expert judgment can be used to estimate production time by asking experts in the manufacturing process to estimate the time it will take to produce a product. This method is most accurate when the experts have experience with similar products and when the manufacturing process is complex.

- Simulation: Simulation can be used to estimate production time by creating a computer model of the manufacturing process and running the model to see how long it takes to produce a product. This method is most accurate when the manufacturing process is complex and when the experts are not available.

Here are some examples of how estimating production time has been used in manufacturing:

- A company used historical data to estimate the production time for a new product. The company found that the production time was significantly longer than they had expected. This allowed the company to adjust their production schedule and avoid production delays.

- A company used expert judgment to estimate the production time for a new product. The experts estimated that the production time would be two weeks. The company was able to start production on the product two weeks before they needed it, which allowed them to meet customer demand.

- A company used simulation to estimate the production time for a new product. The simulation showed that the production time would be four weeks. The company was able to start production on the product four weeks before they needed it, which allowed them to avoid production delays.

Overall, estimating production time is an important part of manufacturing. By using historical data, expert judgment, or simulation, manufacturers can accurately estimate production time and avoid production delays.

4 Use of Markov Chains in Inventory Control

For modeling inventory control systems where product demand is typically random and can only be predicted based on current inventory levels, Markov chains are an obvious choice.

A Markov chain is a mathematical model composed of states and probabilities of transitions. The states represent the various possible inventory level values. The transition probabilities represent the likelihood of transitioning from one state to another (Ata and Özer, 2015).

It is also used to determine the probability that the inventory level will be in a particular state at a given time. This information can then be used to determine production and inventory levels.

In inventory management, Markov chains can be employed to:

- Determine the optimal production quantity: The company can use the Markov chain to calculate the probability that the inventory level will fall below the reorder point at a given time in order to determine the optimal production quantity. The company can then use this probability to determine the optimal production quantity that minimizes lost sales and inventory holding costs.

- Set safety stock levels: Using the Markov chain, the organization can calculate the probability that the inventory level will fall below the safety stock level at a given time. The company can then use this probability to establish safety stock levels that reduce the risk of stockouts.

- The company can use the Markov chain to calculate the probability that the inventory level will be above or below the target level at a given time. The organization can then use this probability to plan production so as to minimize inventory holding costs and production costs.

The Advantages of Utilizing Markov Chains for Inventory Management

Several advantages of Markov chains over conventional inventory control methods include:

- Accuracy: Markov chains can accurately predict inventory levels, leading to improved production and inventory management decisions.

- Markov chains can be used to model a variety of inventory control systems, such as those with stochastic demand and variable production costs.

- Utilizing Markov chains facilitates the calculation of the optimal production quantity, safety stock levels, and production schedules.

Utilizing Markov Chains for Inventory Control Drawbacks

Markov chains also have the following disadvantages:

- For Markov chains to estimate transition probabilities, historical data are required. This information may not be accessible or may be difficult to acquire.

- Markov chains can be challenging to comprehend and implement.

- Computational requirements: Markov chain simulations can be computationally intensive.

Markov chains are an effective method for enhancing the performance of inventory management systems. However, the use of Markov chains in inventory control presents a number of challenges, including data requirements, complexity, and computational demands (Chakraborty and Sarkar, 2017). Despite these obstacles, Markov chains can be a valuable tool for enhancing decision-making, decreasing risk, and increasing the flexibility of inventory control.

4.1 Modelling of Demand Distribution by Using Markov Chains

Demand distribution modeling is the process of developing a mathematical model that represents the probability of demand for a product or service. This model can be used to make decisions regarding inventory, pricing, and marketing campaigns.

Various techniques can be utilized to model the distribution of demand. Using historical demand data, the most common method is to fit a probability distribution to the demand data. The probability distribution can then be applied to demand forecasting (Erol et al., 2018). Demand distributions can be modeled with a number of probability distributions. The following distributions are the most prevalent:

- The normal distribution is a bell-shaped curve that is frequently used to model the demand for relatively stable products.

- The Poisson distribution is a discrete distribution that is commonly used to model random demand for products.

- Gamma distribution: The gamma distribution is a continuous distribution frequently used to model the demand for products with a demand trend.

Several variables impact the selection of demand distribution, including:

- If a product's demand is relatively stable, a normal distribution may be an appropriate choice.

- If demand for a product is random, a Poisson distribution may be an appropriate choice.

- If a product's demand follows a trend, the gamma distribution may be the best option.

Models of demand distribution can be utilized to make a variety of decisions, including:

- Utilizing demand distribution models, the optimal inventory level for a product can be determined. This is the inventory level that minimizes inventory holding costs and the risk of stockouts.

- Utilizing demand distribution models, the optimal price for a product can be calculated. This is the optimal selling price for the product.

- The most effective marketing campaign for a product can be determined using demand distribution models. This campaign will increase demand for the product the most.

The modeling of demand distribution is an effective tool for making better decisions regarding inventory levels, pricing, and marketing campaigns. Understanding product demand and distribution can help businesses improve their bottom line (Giri and Mittal, 2016).

Here are some additional details regarding demand distribution modeling:

- Demand data is frequently fitted to a probability distribution using historical data. This data can be obtained from various sources, such as sales records, customer surveys, and market research.

- Simulation: Simulation can be utilized to validate models of demand distribution. This is achieved by selecting demand values at random from the distribution and comparing the results to actual demand data.

- Utilizing sensitivity analysis, one can determine how alterations in demand distribution impact the optimal inventory level, price, and marketing campaign. This is achieved by modifying the parameters of the distribution and then observing how the results change.

Overall, demand distribution modeling is an effective method for enhancing business performance. Understanding product demand and distribution enables businesses to make more informed decisions regarding inventory levels, pricing, and marketing campaigns.

4.2 Modelling of inventory system by using Markov Chains

The inventory level of a company is the amount of inventory it has on hand. Inventory levels must be accurately estimated to prevent stockouts and guarantee that the company has sufficient inventory to meet customer demand (Khan and Ahmed, 2013).

There are a variety of methods for estimating inventory levels. The most prevalent techniques are as follows:

- Physical count: A physical count is the most accurate way to estimate inventory levels. It involves determining the quantity of each product on hand.

- Cycle counting is less accurate than physical counting for estimating inventory levels, but it is more efficient. It involves counting a portion of the inventory on a regular basis.

- Demand forecasting is a method for predicting future product demand. Adding forecasted demand to current inventory levels can be used to calculate inventory levels.

Each technique is described in greater depth below:

- Physical count: A physical count is the most accurate way to estimate inventory levels. It involves determining the quantity of each product on hand. This can be done manually or through the use of a barcode scanner or other counting device.

- Cycle counting is less accurate than physical counting for estimating inventory levels, but it is more efficient. It involves counting a portion of the inventory on a regular basis. This can be achieved by counting a certain number of items per day or a percentage of the inventory per week.

- Demand forecasting is a method for predicting future product demand. Adding forecasted demand to current inventory levels can be used to calculate inventory levels. Various techniques, such as analysis of historical data, market research, and expert opinion, can be utilized to forecast demand.

The optimal method for estimating inventory levels depends on a number of variables, including:

- The required level of precision: the more precise the estimate, the greater the likelihood that a physical count is the optimal method.

- The cost is: Because physical counts can be costly and time-consuming, cycle counting and demand forecasting may be more cost-effective alternatives.

- The rate at which changes are made. If stock levels must be updated frequently, cycle counting or demand forecasting may be more practical than a physical inventory count.

Inventory management relies heavily on the estimation of stock levels. Companies can ensure they have sufficient inventory to meet customer demand without overstocking by employing the most suitable method for the circumstance ((Kumar and Singh, 2017).

Here are some additional details on the various inventory estimation methods:

- Regular physical counts should be conducted, ideally at least once a year. If inventory levels are volatile or there is a risk of stockouts, more frequent physical inventory counts may be required.

- Cycle numbering: Cycle counting can be performed weekly, monthly, or quarterly, depending on the business's needs. It is essential to choose a cycle counting frequency that will allow the business to maintain accurate inventory levels with minimal operational disruption.

- Forecasting demand can be a complicated process, and there is no "best" method. The optimal method for a particular business will depend on its nature, the products sold, and the availability of data.

Inventory management relies heavily on the estimation of inventory levels. Companies can ensure they have sufficient inventory to meet customer demand without overstocking by employing the most suitable method for the circumstance (Liu and Sun, 2018; Ren et al., 2017).

5 Markov Chains for Quality Control

In recent years, quality control has also grown in popularity. By analyzing the probability of defects occurring at each stage of the manufacturing process, businesses can identify areas for improvement to increase efficiency and reduce waste. This method has been successfully implemented in industries ranging from electronics to food production, resulting in substantial cost savings and improved product quality. Markov models have been also utilized to analyze customer behavior and predict future purchasing patterns. Companies can tailor their marketing strategies to better meet the needs of their target audience if they comprehend the various stages of the purchasing process. In conclusion, Markov transition models are a flexible and potent instrument for analyzing complex systems and making data-driven decisions in a variety of industries (Singh and Kumar, 2017; Wang and Zhang, 2017).

Alam and Kabir (2015) studied on use of Markov Chains on quality control of manufacturing processes. They found out that Markov chains can be also used to simulate the probability of product defects, the cost of locating and correcting defects, and the cost of sales lost as a result of defects. Using this information, you can determine the optimal quality control strategy for meeting customer expectations and minimizing quality expenses.

The following are some specific applications of Markov chains in quality control:

- Markov chains can be used to detect potential flaws in products by tracking the occurrence of flaws over time (Bai and Wang, 2018). Using this information, it is possible to identify the manufacturing process steps where errors are most likely to occur. Based on past occurrences, Markov chains can also be used to predict the likelihood of future flaws. By analyzing the patterns of defect occurrence, manufacturers can take preventative measures to eliminate defects. To analyzing customer reviews, Markov chains can also be used for quality control by analyzing customer feedback. Using techniques for sentiment analysis and natural language processing, manufacturers are able to identify recurring themes and issues in customer complaints. This data can then be used to enhance product design and manufacturing techniques, ultimately resulting in an increase in customer satisfaction. Predictive maintenance employs Markov chains to monitor equipment performance in order to predict when maintenance is required. Utilizing Markov chains, manufacturers can anticipate when equipment will fail and plan maintenance based on failure and repair data. This strategy ensures that the equipment is always operating at peak performance while minimizing maintenance costs and downtime. In conclusion, Markov chains are a useful instrument for manufacturing quality control. Customer feedback and data on the occurrence of defects are examined.

- Markov chains can be utilized to prevent defects by identifying their origins. Changes can be made to the manufacturing process to reduce the likelihood of defects occurring, based on the information provided (Cai et al., 2019). By analyzing trends in defect occurrences, Markov chains can also be used to foresee upcoming defects. This enables manufacturers to take preventative measures prior to the occurrence of a defect. Additionally, Markov chains can be utilized to enhance the manufacturing process by identifying areas where modifications can be made to reduce the likelihood of errors. By employing Markov chains in defect prevention and optimization, manufacturers can simultaneously improve product quality and reduce costs associated with defective products. Overall, Markov chains offer manufacturers a potent tool for detecting and preventing potential flaws in their products, which boosts customer satisfaction and profits.

- Errors can be detected using Markov chains by scanning the output of a manufacturing process. This information can be utilized to identify defective products prior to their delivery to customers. Markov chains can be used to improve manufacturing procedures in addition to preventing and detecting defects. By analyzing supply chain data, manufacturers can identify areas for improvement to increase efficiency and reduce waste (Chen and Li, 2018). This information can be used to modify the manufacturing process, such as machine settings or the order of operations, in order to increase output and reduce costs. Markov chains can also be used for predictive maintenance, enabling manufacturers to anticipate when machines will need maintenance or repairs before they fail. This ensures production continues uninterrupted and helps to prevent costly downtime. In general, Markov chains are an effective tool for manufacturers seeking to increase process productivity and quality control.

- Markov chains can be used to fix flaws by determining the optimal method for repairing damaged goods. Utilizing this information will reduce the cost of repairing defective goods (Elmaghraby, 2003). Markov chains can be used to improve the manufacturing process in addition to detecting and correcting defects. Using Markov chains, it is possible to examine manufacturing process data to identify areas for error reduction and productivity enhancement. Using this data, the manufacturing procedure can be modified by adjusting the temperature or pressure settings or rearranging certain steps. By continuously monitoring and enhancing the manufacturing process with Markov chains, businesses can reduce costs, enhance product quality, and boost customer satisfaction. To achieve the best results, Markov chains should be combined with techniques such as statistical process control and Six Sigma methodologies. Markov chains are only one of many quality assurance techniques available.

- By identifying the most cost-efficient methods for defect detection, prevention, and correction, Markov chains can be used to reduce quality costs (Ghosh and Das, 2019). Utilizing this information will reduce quality costs while simultaneously improving product quality.

Markov chains have shown promise in event prediction as well. On the basis of previous occurrences, they can be used to predict the likelihood of a specific event occurring. This information makes it possible to make informed decisions and take appropriate action (Khoshnevisan and Zhang, 2018; Kouvelis and Murray; 1993). In finance, Markov chains have been utilized to forecast market trends and model stock prices. In natural language processing, they have also been used for speech and text recognition. Markov chains have been utilized in the healthcare industry to model disease progression and predict patient outcomes. Overall, the adaptability of Markov chains makes them a valuable instrument for process optimization, cost reduction, and event prediction in a vast array of fields and industries (Liu and Li, 2015; Wang and Bai, 2016).

6 Limitations of Markov Chains

Markov chains are an effective modeling technique for a wide variety of systems, including production and inventory systems. However, there are several disadvantages to employing Markov chains in such systems. The assumption that the future state of a system is solely determined by its current state is a limitation of Markov chains. Other factors, such as weather or economic conditions, can influence the future state of a system, so this assumption is not always true.

Another drawback of Markov chains is that their implementation is computationally intensive. Due to the fact that Markov chains require the calculation of transition probabilities, which can be time-consuming for large systems, this is the case. Despite their limitations, Markov chains are widely employed in numerous fields, such as finance, engineering, and biology. In finance, Markov chains are used to model stock prices and predict market trends. In engineering, they are used to simulate the behavior of complex systems like power grids and transportation networks. In biology, Markov chains are used to model cell behavior and predict the spread of disease. In order to address the issue of computational complexity, researchers created techniques such as parallel computing and Monte Carlo methods to accelerate the calculation of transition probabilities. In addition, researchers have investigated the use of deep learning techniques to improve the accuracy of Markov chain models by incorporating additional factors that can influence the future state of a system. Despite their limitations, Markov chains continue to be a valuable modeling and prediction tool for complex systems. Markov chains assume that a system's future state is solely determined by its present state. Other factors, such as weather or economic conditions, can influence the future state of a system, so this assumption is not always true. For instance, if a company manufactures a weather-dependent product, such as an umbrella, the weather may affect the product's demand. This indicates that the Markov chain model cannot accurately forecast product demand. Utilizing Markov chains can be computationally costly. Due to the fact that Markov chains require the calculation of transition probabilities, which can be time-consuming for large systems, this is the case. For instance, if a company manufactures a product, such as a car, with a large number of possible states, the Markov chain model must calculate a large number of transition probabilities. This can increase the computational cost of using the model.

Markov chains can be an effective modeling tool for production and inventory systems, despite their limitations. To obtain the most precise results, it is necessary to be aware of the limitations of Markov chains and to use them in conjunction with simulation and heuristics.

7 Alternatives to Markov Chains

There are numerous modeling tools for production and inventory systems. Among these tools are discrete event simulation, the theory of queueing, and dynamic programming. Simulation of discrete events enables the modeling of complex systems with multiple processes and resources. In systems with queues, waiting times and resource utilization can be analyzed using queueing theory. Dynamic programming is a mathematical optimization technique that can be used to identify optimal policies for inventory system decision-making. Each of these tools has its own advantages and disadvantages, and the choice of which tool to employ is contingent on the particular characteristics of the system being modeled. Before selecting a tool for modeling a production or inventory system, it is essential to carefully consider the assumptions and limitations of each one. In the end, the most effective method may involve combining these tools with expert knowledge and discretion to develop a comprehensive understanding of the system and make informed management decisions.

Simulation is an effective method for simulating the behavior of a system. Simulation can be used to examine the effects of system modifications on the outcomes of various scenarios. It enables the identification of potential system bottlenecks and inefficiencies and the optimization of resources and processes. However, simulation requires a substantial amount of data and may not always accurately reflect real-world circumstances. Optimization, which entails locating the optimal solution to a problem given a set of constraints, is a second tool for modeling production or inventory systems. Optimization can be used to determine the most effective allocation of resources or to reduce expenses while maintaining quality standards. However, it heavily relies on assumptions and simplifications that may not always be valid in practice. In conclusion, statistical analysis can be used to identify patterns and trends in data, thereby facilitating improved forecasting and decision-making. Statistical analysis can also be utilized to monitor system performance and identify improvement opportunities. However, it necessitates a solid grasp of statistical methods and may not always yield actionable insights. Ultimately, the appropriate tool for modeling a production or inventory system is determined by the organization's specific needs and objectives, as well as the availability of data and resources.

Heuristics are rules of thumb that can be utilized to make decisions regarding production and inventory. Heuristics can aid in decision-making, but they are not always as precise as other methods. For more accurate results, statistical methods are frequently employed. However, these techniques necessitate a solid grasp of statistics and may not always yield actionable insights. When selecting a modeling tool for a production or inventory system, it is essential to consider the organization's specific needs and objectives. In addition, the availability of data and resources must be considered. Finding the appropriate modeling tool for a production or inventory system ultimately requires careful consideration and analysis. By considering these factors, organizations are able to make decisions that improve their efficiency and profitability.

Expert systems are computer programs that are able to make decisions based on specialized knowledge. Expert systems can be useful for making complex decisions, but their development and maintenance are costly. They may not always be able to adapt to new information or circumstances. Machine learning algorithms, which can analyze large amounts of data, identify patterns, and make predictions, are another option for decision-making. However, these algorithms require vast quantities of information and may not always be accurate. Additionally, simulation software can be used to model production or inventory systems and test various scenarios without disrupting actual operations. Before implementing changes, this can help organizations identify potential problems and optimize their processes. Overall, the choice of tool will depend on the organization's specific requirements and available resources, as well as the complexity of the system being modeled. Finding the optimal solution for increasing production or inventory management's profitability and efficiency requires careful consideration and analysis.

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Chapter 7

AUTONOMOUS WATER VEHICLE DESIGN BASED ON STRANDBEEST MECHANISM BY MIMICKING ROWING MOTION

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1. Introduction

A marine propulsion system encompasses the technology utilized to propel waterborne vessels. These systems adhere to Newton's third law of motion. In the context of marine propulsion, the propulsion device generates a force on either the surrounding water or air, resulting in a reaction force being exerted on the vessel, propelling it in the desired direction. For instance, propellers exemplify this principle by exerting a force on the water, pushing it backward or forward, while experiencing an equal and opposite force in the opposite direction. If this force is of sufficient magnitude, it imparts motion to the vessel on the water. Similar principles apply to hovercraft fans or wind sails, where forces are applied to the surrounding air to generate propulsion.

There are several marine propulsion systems such as (Nautilus, 2023):

- Propellers: These are the most common type of propulsion system used in watercraft. Propellers consist of rotating blades that generate thrust by pushing water backward, propelling the vessel forward.

- Water Jets: Water jet propulsion systems utilize high-pressure jets of water to propel the vessel. Water is drawn in through an intake, compressed, and expelled through a nozzle at high velocity, creating forward thrust.

- Outboard Motors: Outboard motors are self-contained units that combine an engine, gearbox, and propeller. They are typically mounted on the transom of small boats and provide propulsion and steering control.

- Sail Propulsion: Sail propulsion harnesses the power of the wind to propel a vessel. Sails capture the force of the wind and convert it into forward motion. This type of propulsion is commonly used in sailboats and yachts.

- Water Rockets: Water rockets use pressurized water expelled through a nozzle to generate thrust. These propulsion systems are often used in recreational water toys or experimental watercraft.

- Electric Motors: Electric propulsion systems utilize electric motors powered by batteries to propel the vessel. They offer quiet operation, zero emissions, and are commonly used in electric boats and smaller watercraft.

- Gas Turbines: Gas turbine propulsion systems use combustion of fuel to drive a turbine, which in turn drives the propeller. They are commonly found in high-speed vessels such as naval ships and fast ferries.

- Human-powered propulsion system: Human-powered propulsion systems have a long-standing history in marine transportation. Before the advent of steam engines, human muscle was the primary source of propulsion for various types of ships. In the absence of wind, humans relied on paddles, oars, and other equipment to propel vessels through the water. This method of propulsion was utilized in a wide range of vessels, including fishing boats and war galleys. Even today, human-powered vessels continue to be present in both commercial shipping and recreational activities.

Rowing is a time-honored human practice in which a boat, known as a shell, is propelled solely by the muscular power of one or more individuals operating oars (Sforza et al., 2012). The rowing motion engages both the limb and trunk muscles, demanding well-coordinated movements and balance. Rowing encompasses a cyclical process consisting of four distinct phases: the catch, drive, finish, and recovery. During the catch phase, rowers assume a compressed posture, with flexed legs and anterior trunk rotation at the pelvis, while extending their arms and elevating their hands to position the oar blade perpendicular to the water's surface. Subsequently, the drive phase commences, characterized by forceful leg extension, posterior trunk rotation, and the pulling of the oar handle towards the rowers' chest or abdomen. At the finish, the hands are lowered to raise the oar blade from the water, and precise timing is crucial to ensure an efficient stroke. Delayed blade extraction can lead to undesirable contact between the water and the back of the blade, negatively impacting boat velocity, while premature extraction diminishes stroke efficiency (Spracklen, 2005). As the oar blade is extracted, the oar shaft undergoes rotational movement along its longitudinal axis, resulting in blade feathering, where the blade surface aligns parallel to the water's surface. The recovery phase initiates with the rowers pushing their hands away from their bodies, accompanied by anterior trunk rotation and knee flexion as the hands pass the knees. Ultimately, the rowers return to the compressed position at the end of the slide, poised for the subsequent catch (Caplan, Coppel, & Gardner, 2010).

Over time, various rowing techniques have been developed, accompanied by modifications to the shell and oars (Baudouin & Hawkins, 2002). However, a successful rowing technique hinges on maximizing the horizontal direction of the rowing stroke, aligning it parallel to the water's surface, to effectively utilize the propulsive force generated (Baudouin & Hawkins, 2004, McGregor, Bull, & Byng-Maddick, 2004). The main forces during one cycle of rowing can be found in (Kleshnev, 2010).

The Strandbeest, conceptualized and developed by Theo Jansen, represents a remarkable collection of beach animals that possess the ability to survive autonomously (Wang & Hou, 2018, Since 1990, Jansen, 2007). Jansen has continuously refined and enhanced these unique creations, which are primarily constructed using non-biological materials such as PVC plastic pipes and wood. By incorporating mechanical principles and harnessing wind power, the Strandbeest exhibits bionic dynamics, enabling it to walk and navigate simple obstacles (Komoda & Wagatsuma, 2012). Over time, the Strandbeest has undergone generational evolution, resulting in various types with diverse capabilities (Wang & Hou, 2018).

The foot working system utilized by the Strandbeest is referred to as "Jansen's Linkage" (Jansen, 2007). This mechanism, characterized by a fixed ratio of rods, facilitates walking motion. Jansen's Linkage, which forms part of the overall leg mechanism, finds applications in the field of mobile robotics and gait analysis. The linkage mechanism comprises a combination of ten rods of varying lengths, along with the crank's length and a fixed point, resulting in a total of 12 distance compositions. Figure 1 shows a typical Strandbeest mechanism.

2. Materials and Method

The Theo Jansen mechanism is characterized by its single degree of freedom, consisting of eight points and twelve links. This mechanism exhibits four closed loops, allowing for various motion outputs. By adjusting the positions of the fixed points and the lengths of the connecting links, the motion output of the mechanism can be modified. Dimension of links are shown in Figure 1.

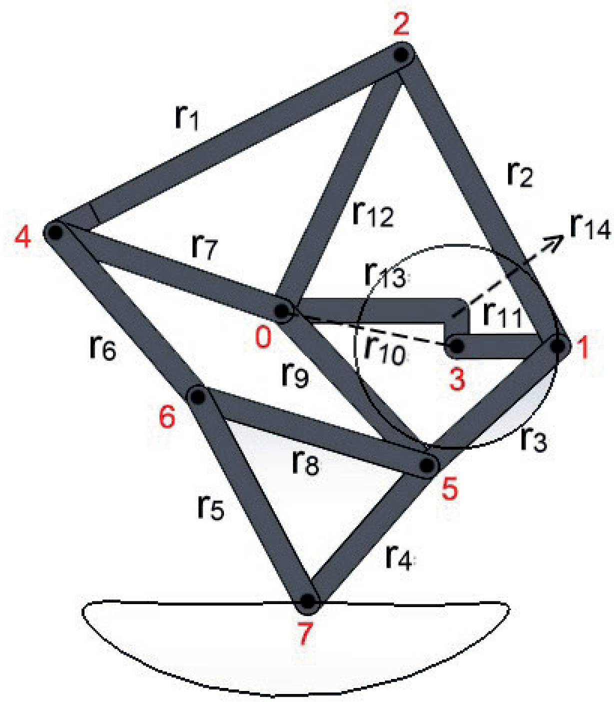

Figure 1 *Strandbeest mechanism, and its dimensions.*

2.1 Kinematic Analysis of the Mechanism

Theo Jansen's mechanism involves a total of 14 parameters, encompassing 12 link lengths and 2 fixed points. By adjusting specific parameters, the motion generated at "Point 7, which is the end effector" can be altered. The kinematic analysis was carried out using multi-body dynamic simulation program: MSC ADAMS. Through a complete rotation of the crank (360 degrees), the positions of the points were analyzed. Initial values and final values of the link dimensions are given in Table 1.

Table 1 *Initial and final value of the constructional parameters of the mechanism links.*

Name of the Link	Initial values in mm	Final values in mm
r_1	55.80	134.36
r_2	50.00	114.48
r_3	61.90	61.50
r_4	49.00	62.44
r_5	65.70	80.24
r_6	39.40	75.00
r_7	40.10	82.34
r_8	36.70	82.20
r_9	39.30	73.70
r_{10}	38.79	79.58
r_{11}	15.00	35.14
r_{12}	41.50	97.94
r_{13}	38.00	60.32
r_{14}	7.80	12.34

3. Results and Discussion

In this section, the kinematic and kinetic analysis results of the Strandbeest mechanism with the final value of the dimensions of the links, are given. Figure 2 shows the obtained position of the oar in time domain and spatial domain. The oar has the position in X axis -100 mm and 5* mm with a periodicity. The periodic behavior of the oar is due to the full complete rotation of the rotating link. The oar moves from -140 mm to -110 mm in Y axis. In the spatial domain (position of the oar on X-Y plane), the results demonstrate that the position of the oar obtained with the final dimensions of the links is similar to the rowing motion. In this motion the cycle of the rowing consisted of a sweeping in the water during the required work and return of the oar with minimal deviation from a straight trajectory in the air for the minimal energy consumption.

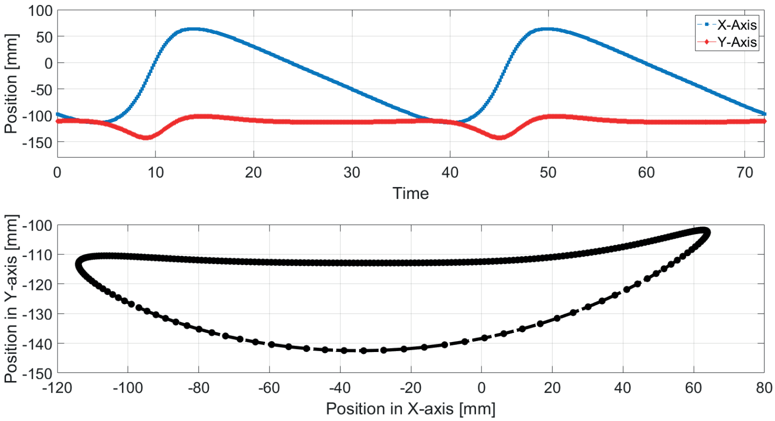

Figure 2 *The position of the oar with the given final dimensions of the links in the Strandbeest mechanism in time domain and spatial domain.*

Figure 3 and Figure 4 show the velocity of the oar in time domain, and with respect to the rotating angle, respectively. The oar moves with a maximum velocity of 40 mm/sec in X axis and 13 mm/sec in Y axis. At some position of the rotating link around 150 deg, the velocity of the oar becomes constant. The constant velocity regime belongs to the returning cycle of the oar.

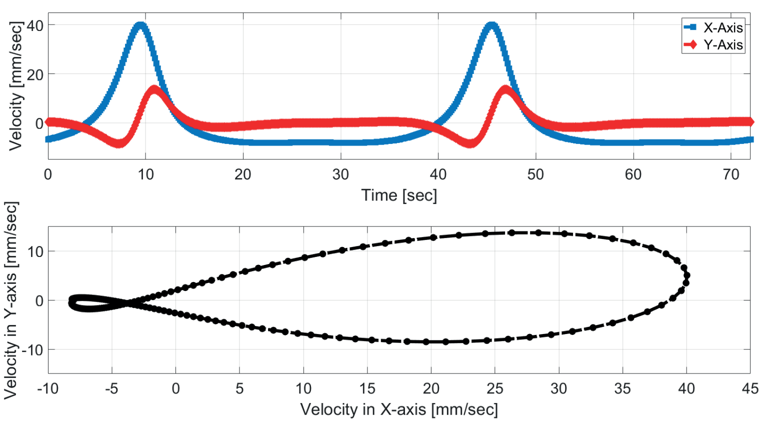

Figure 3 *The velocity of the oar with the given final dimensions of the links in the Strandbeest mechanism in time domain.*

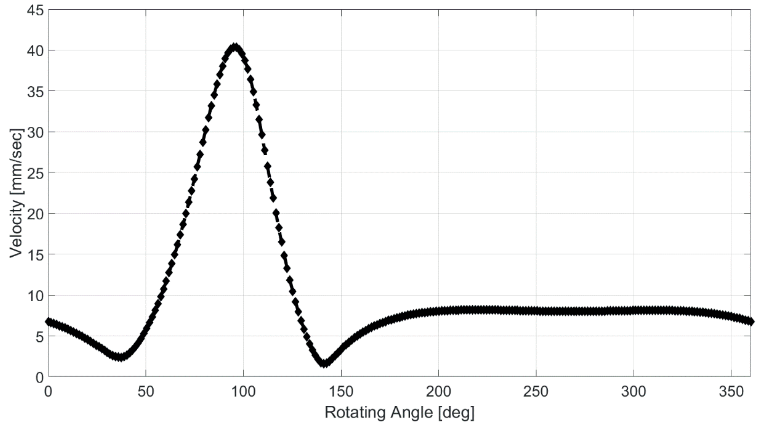

Figure 4 *The velocity of the oar with the given final dimensions of the links in the Strandbeest mechanism with respect to the angle of the rotating link.*

Figure 5 and Figure 6 show the linear acceleration of the oar in time domain, and with respect to the rotating angle, respectively. The acceleration takes place between -15 to 12 mm/sec^2 in X axis, and -5 to 12 mm/sec^2 in Y axis. Between the angular position of the rotating link of 50 to130 deg, the acceleration becomes the maximum value. This section is the work completed section, where the oar is in the water.

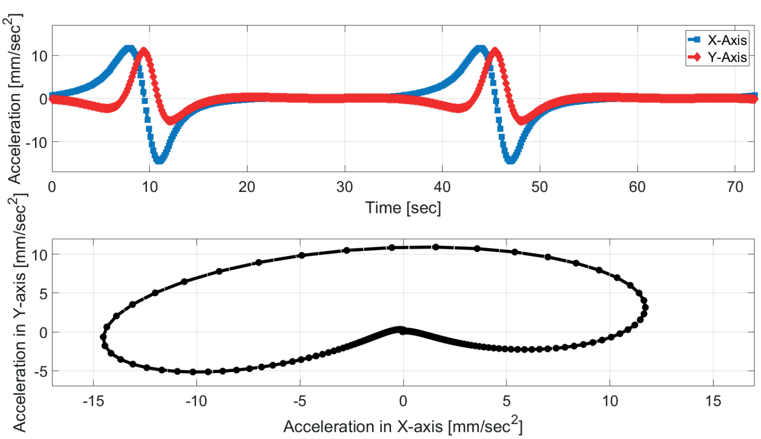

Figure 5 *The acceleration of the oar with the given final dimensions of the links in the Strandbeest mechanism with respect to the angle of the rotating link.*

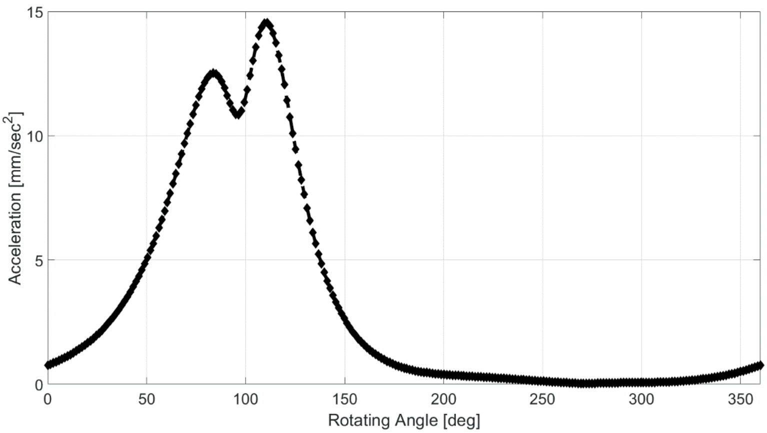

Figure 6 *The acceleration of the oar with the given final dimensions of the links in the Strandbeest mechanism with respect to the angle of the rotating link.*

Figure 7 shows the angular velocity and accelerationb of the oar in time domain. The angular velocity has a maximum value of 16 rad/sec, and the angular acceleration has the maximum value of approximately 7 rad/sec^2. During the full cycle a typical rowing motion and full rotation of the rotating link, the angular acceleration becomes almost zero in the return cycle. This is expected since the oar moves almost in a straight trajectory as shown in Figure 2.

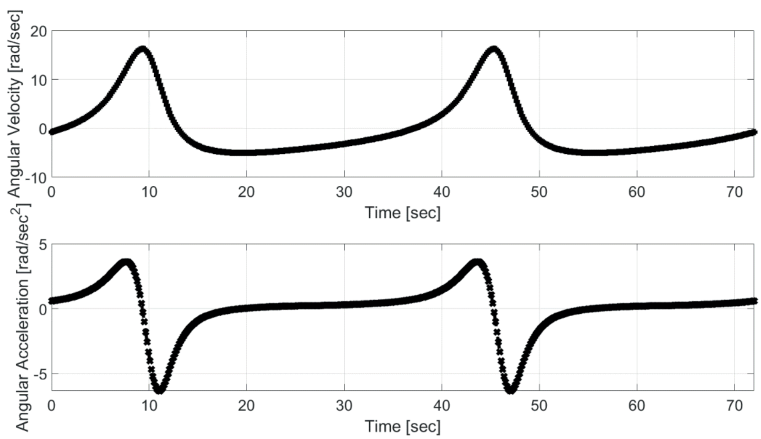

Figure 7 *The angular velocity and angular acceleration of the oar with the given final dimensions of the links in the Strandbeest mechanism in time domain.*

Figure 8 and Figure 9 gives the results of the required torque and power consumption during a full rotation of the rotating link. Two results are given.

One is related to the kinetic analysis, where there is no force acting on the oar. In the second one, a force representing the fluid (water) force is applied to the oar to the opposite direction of the oar motion in the X-axis. And, two force values are considered. The results show that the torque required during a full cycle of the rowing mimicked motion is around 220 Nmm and 420 Nmm, when the fluid force is 1 N, and 2 N, respectively. The power consumption for the possible actuator such as a direct-current electrical motor, is around 40 mW, and 220 mW, when the fluid force is 1 N and 2 N, respectively. The maximum torque and power consumption occured in the regime, where the oar is in the water.

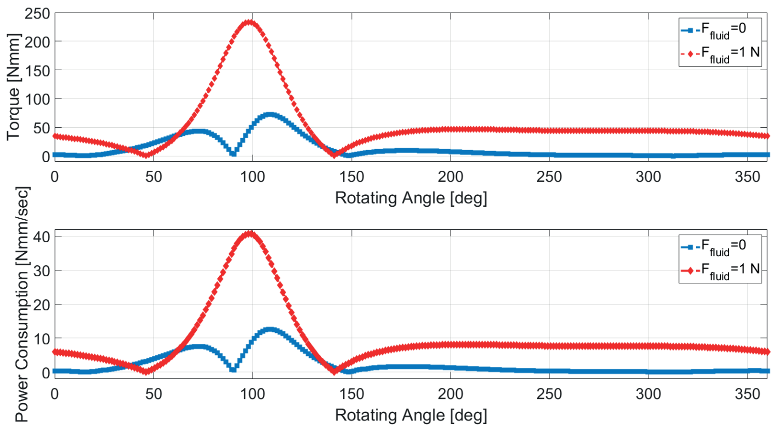

Figure 8 *The torque and power consumption of the rotating link with the given final dimensions of the links in the Strandbeest mechanism with respect to the angle of the rotating link, when there is no fluid force, and there is a fluid force with a magnitude of 1 N.*

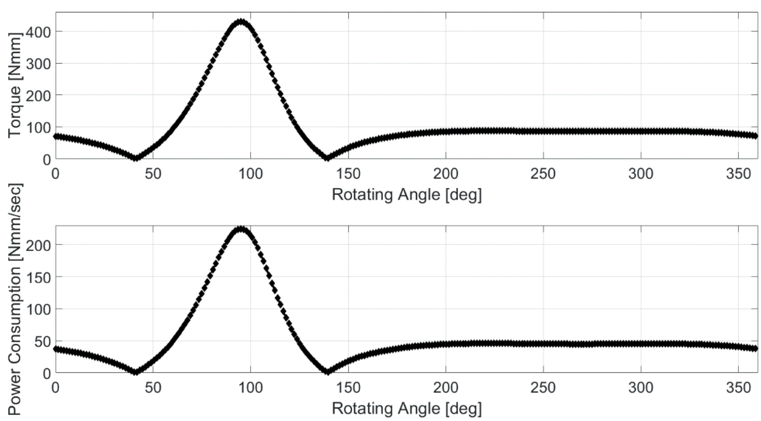

Figure 9 *The torque and power consumption of the rotating link with the given final dimensions of the links in the Strandbeest mechanism with respect to the angle of the rotating link, when there is a fluid force with a magnitude of 2 N.*

4. Final Design

This section covers gives a typical final design configuration of an autonomous water vehicle design based on mimicking the rowing motion and using a single-degree-of-freedom mechanism, Strandbeest. Figure 10 shows the final design of the autonomous water vehicle. The design consists of using two individual Strandbeest mechanism with the given final dimensions of the links. The usage of two Strandbeest mechanism allows to be able to maneuver with a desired rotational motion.

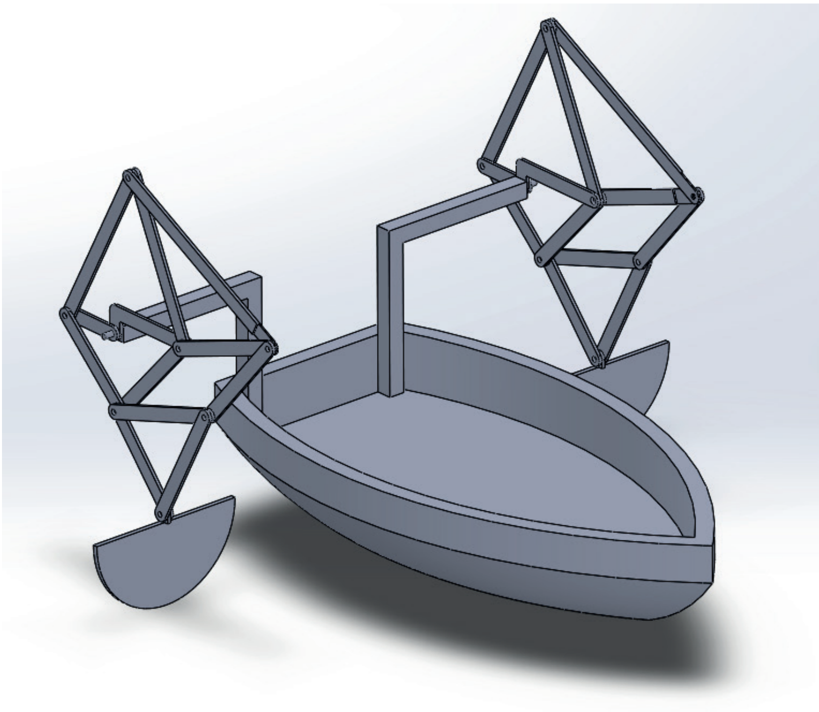

Figure 10 *Final Design of the autonomous water vehicle.*

5. Conclusion

In this study, it was aimed to autonomize a water vehicle by using a single-degree-of-freedom mechanism while mimicking a rowing motion. Since the Strandbeest is simply a single-degree-of-freedom mechanism, it can be easily automized by just simply providing a fully rotational motion to the rotating link (r_{11}). This could be easily obtained by using a direct-current electrical motor. Additionally, with two individual Strandbeest mechanism allows to be able to rotate the water vehicle for a desired maneuver motion.

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Chapter 8

DEFORMATION ANALYSIS OF ANGLED FIBER COMPOSITE PLATE UNDER IN-PLANE LOAD

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1. INTRODUCTION

Composite is a building material consisting of two or more components that are brought together at a macroscopic level and that do not dissolve in each other. One of the components is called the reinforcement phase and other is called the matrix. Material of the reinforcement phase may be in the form of fibers, flakes or particles. Materials of the matrix generally have a continuous structure (Kaw, 2006). Advantageous properties of composite material such as ideal hardness, high rigidity, high strength/weight ratio are important for high performance applications. With these features that monolithic materials do not have, it meets the needs of today's advanced technologies. At the same time, properties of the composite materials are function of the properties of its elements, size, structure of the reinforcing sheets, including the shape, amount, distribution, and particles or orientation of the fibers (Jones, 1975). Important applications of composite sheet materials in automotive engineering, robotics, shipbuilding structure, aerospace, submarines, medical instruments, space navigation and many industries are an excellent process for accurate prediction of structural behavior (Maji and Mahato, 2022).

The more widespread adoption of composite materials in the design phase of engineering products is directly related to the level of knowledge on deformations. Especially at this point, it is the structural modeling problem of composite materials. It is the delamination of the structural material and elements under the influence of shock loads that usually cause deformation. This indicates the importance and suitability of working on composite materials and the need to develop special processes with it (Smith, 1998). Composite plates are structures that can be exposed to intense dynamic loads. One of the research methods for the behavior of the most general non-canonical plates under load is finite element method. Theoretical methods have not been sufficiently developed, and this is due to the complexity of the mathematical models describing the deformation process and the intense short-term effects (Smetankina et al., 2021).

The data-based approach is an emerging new field of computational analysis and a classic approach to mathematical modelling. A common feature of the traditional method in the mechanics of a deformable product is the formulation of design-specific models. Such models involve variables or functions that will be determined by the results of a series of physical experiments. Homogeneous materials present several challenges in the conventional method approach. There are a number of fundamental experiments on internal structural heterogeneity and problems for heterogeneous materials and the significant distribution of experimental data. Composite materials, especially modern production technology, do not allow the components in their structure to be obtained stably. In such cases, the use of numerical processing methods, the problems of defining the inaccuracy of material parameters, are important issues to be considered in the models (Sousa et al., 2016). Using the new computing paradigm allows you to use large quantities directly. Experimental data are taken into account for the numerical solution of boundary value problems of continuity mechanics. This eliminates the possibility of incorrect modeling of material models and errors in formulation (Lvov and Kostromytska, 2020).

Deformation in an object under load is undesirable. Design parameters and material structure are the two most important factors affecting deformation. Therefore, before transforming the design into the final product, deformation analyzes should be performed and its suitability for process conditions should be evaluated. In this study, the mechanical behavior of graphite fiber epoxy matrix, aramid fiber epoxy matrix, glass fiber epoxy matrix cantilever composite plates for fiber angles under in-plane load was investigated by using Von Mises Yield Criterion with a simulation program based on finite element method (FEM).

2. MATERIAL AND METHOD

The geometry of fiber reinforced composite plate under in-plane total P load in figure 1 and geometry of the sandwich composite plate in figure 2.

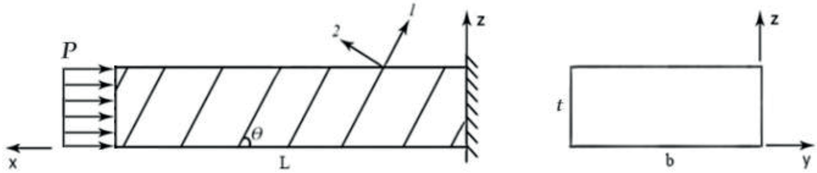

Figure 1. Geometry of cantilever composite plate under in-Plane Load

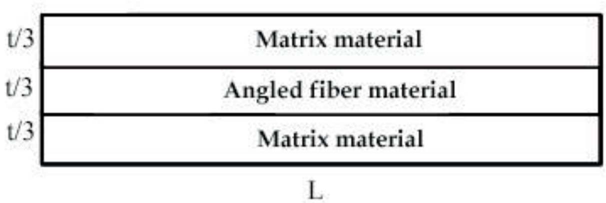

Figure 2. Geometry of the sandwich composite plate

In Figure 1, ϴ shows axes 1-2 represents axes of fibers and x,y,z represents the axes of the composite plate and fiber angles. Structure of the composite plate is sandwich composite as composite type. A sandwich composite material consists of two layers of matrix material and one layer of fiber material (Figure 2). Its structure is respectively matrix material, fiber material and matrix material.

Dimension and load properties of composite plate are given in Table 1, mechanical properties of epoxy materials, aramid fiber, graphite fiber, glass fiber are given in Table 2.

Table 1.
Dimensional and load properties of the sandwich composite plate

P (N)	L (mm)	t (mm)	b (mm)
1000	300	15	150

Table 2.
Mechanical properties of the epoxy matrix and fibers (Kaw, 2006)

Mechanical Properties	Graphite Fiber Material	Glass Fiber Material	Aramid Fiber Material	Epoxy Matrix Material
Longitudinal module (GPa)	230	85	124	3.4
Transverse module (GPa)	22	85	8	3.4

Longitudinal poisson's ratio	0.30	0.20	0.36	0.3
Transverse poisson's ratio	0.35	0.20	0.37	0.3
Longitudinal shear module (GPa)	22	35.42	3	1.308
Longitudinal tensile strength (MPa)	2067	1550	1379	72
Longitudinal compressive strength (MPa)	1999	1550	276	102
Transverse tensile strength (MPa)	77	1550	7	72
Transverse compression strength (MPa)	42	1550	7	102
Shear strength (MPa)	36	35	21	34

2.1. Nodal Parameters and Displacement Functions

Quadratic multi-layer composite plate ingredient is in figure 3. Displacement components of v_{0j} of reference xy plane side displacements w_j , node j occur of in-plane displacements u_{0j}, normal rotations Θ_{xij} in each layer. These can be occured by vector:

$$\{\delta_j\} = \{u_{0j}, v_{0j}, w_j, \theta_{x1j}, \theta_{y1j}, \theta_{x2j}, \theta_{y2j}, ..., \theta_{xmj}, \theta_{ymj}\}^T \tag{1}$$

element displacement by vector is

$$\{\delta\} = \{\delta_1, \delta_2, ...\delta_8\}^T \tag{2}$$

where m is total number of layers.

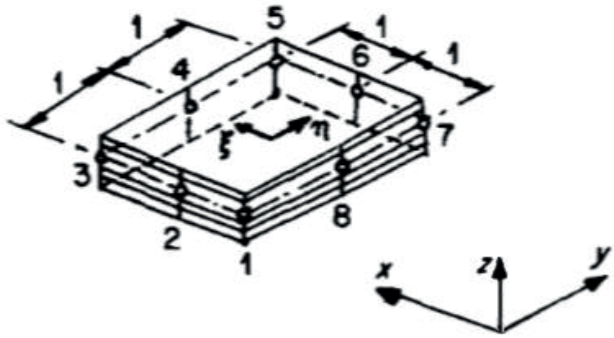

Figure 3. Quadratic multilayer composite plate element (Mawenya and Daveis, 1974)

A shape function definition is adopted to describe the displacements of any point (x, y, z) in ith layer in terms of node displacements as follows (Mawenya and Daveis, 1974):

$$u=\sum_{j=1}^{8} N_j \left\{ u_{0j} - qt_1\theta_{x1j} - \sum_{p=2}^{i-1} t_p\theta_{xpj} - \left(\frac{1}{2}t_i + z_i\right)\theta_{xij} \right\} \quad (3)$$

$$v=\sum_{j=1}^{8} N_j \left\{ v_{0j} - qt_1\theta_{y1j} - \sum_{p=2}^{i-1} t_p\theta_{ypj} - \left(\frac{1}{2}t_i + z_i\right)\theta_{yij} \right\} \quad (4)$$

$$w=\sum_{j=1}^{8} N_j w_j \quad (5)$$

where Nj are simple isoparametric shape functionsn ξ and μ coordinates by the following equations. At corner nodes *(*Mawenya and Daveis, 1974):

$$N_j = \frac{1}{4}\left(1+\xi_0\right)\left(1+\mu_0\right)\left(\xi_0+\mu_0-1\right) \quad (6)$$

2.2. Finite Element Analysis

Figure 4 shows the composite plate under plane load analyzed in SolidWorks Simulation using the finite element method. Dimensional and load properties of the sandwich composite plate in Table 1, mechanical properties of epoxy matrix and fibers in Table 2, and the structure in Figure 1-2 were used in this analysis. The sandwich composite plate cantilevered by applying an in-plane load P. Von Mises Yield Criterion used in the analysis. Meshing size applied as 2 mm trigonal mesh section of composite plate is in Figure 5.

Figure 4. Boundary conditions applied composite plate model

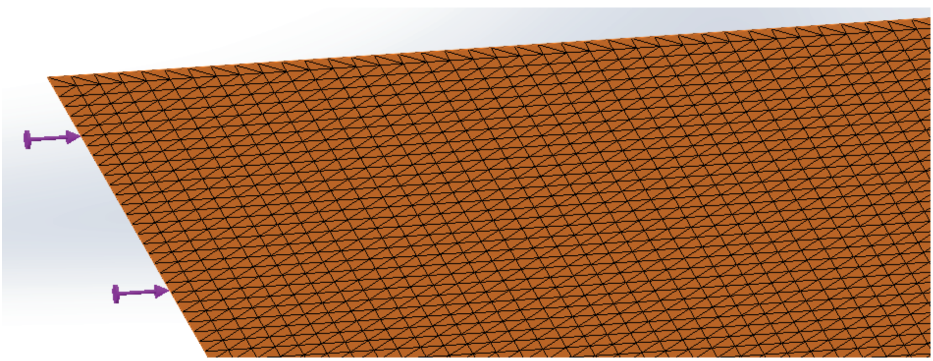

Figure 5. The meshed geometry section of the composite plate

3. RESULTS

Deformation results for fiber angles of graphite fiber epoxy matrix sandwich composite plate are in figure 6, glass fiber in figure 7 and aramid fiber in figure 8.

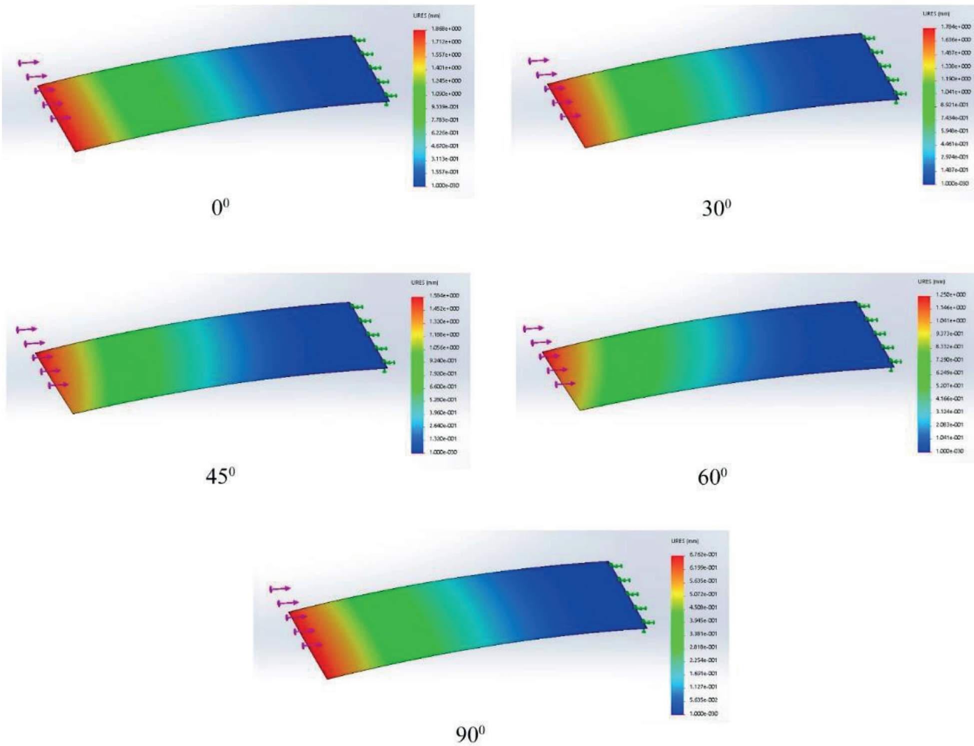

Figure 6. Deformation results for fiber angles of graphite fiber epoxy matrix sandwich composite plate

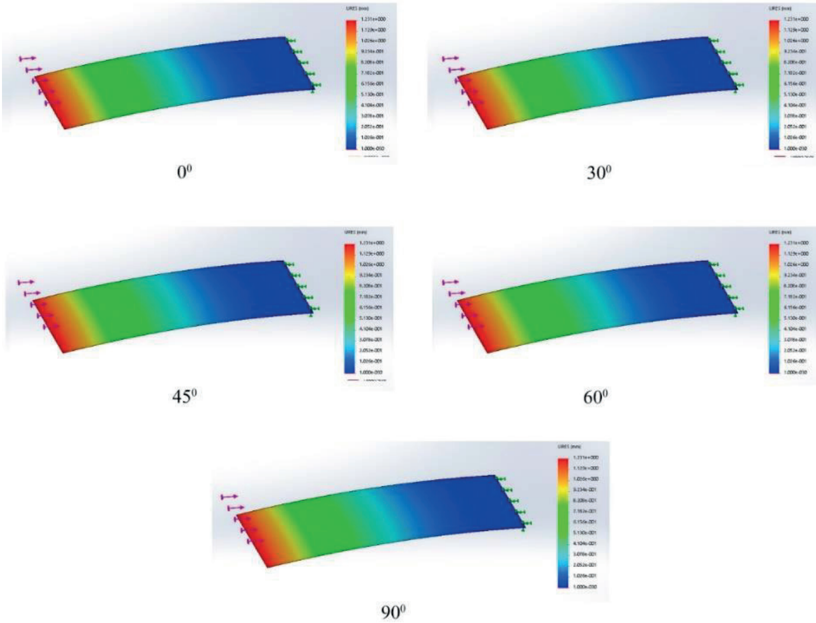

Figure 7. Deformation results for fiber angles of glass fiber epoxy matrix sandwich composite plate

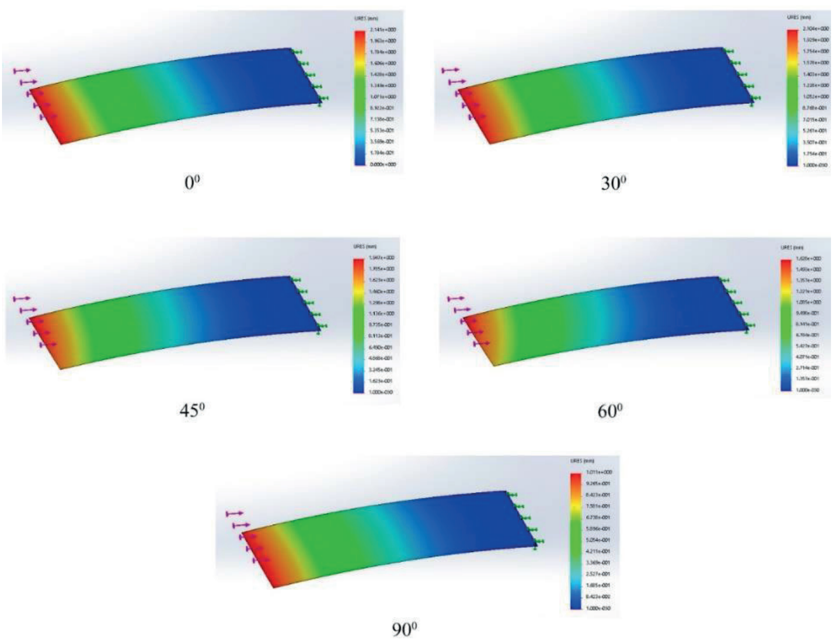

Figure 8. Deformation results for fiber angles of aramid fiber epoxy matrix sandwich composite plate

Maximum deformation results for fiber angles of the composite plates are in table 3 and graphic of results' in figure 9.

Table 3.
Maximum deformation values for fiber angles of the composite plates

Fiber Angle (degree)	Graphite Fiber Epoxy Matrix (mm)	Glass Fiber Epoxy Matrix (mm)	Aramid Fiber Epoxy Matrix (mm)
0	1.868	1.231	2.141
30	1.784	1.231	2.104
45	1.584	1.231	1.947
60	1.250	1.231	1.628
90	0.676	1.231	1.011

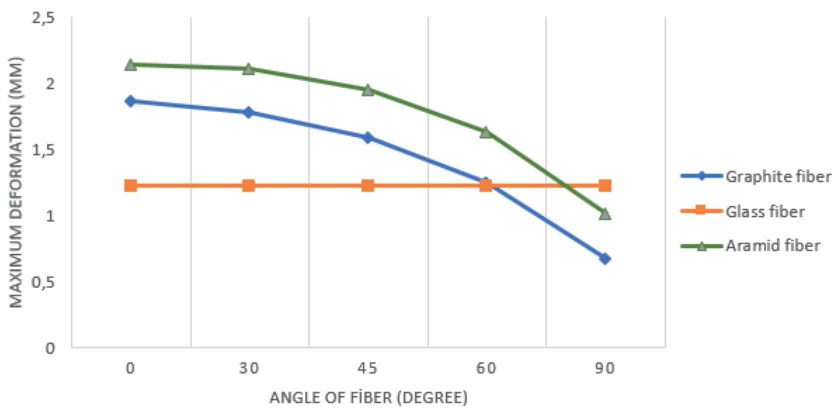

Figure 9. Maximum deformation graph for fiber angles of composite plates

4. CONCLUSION

- The highest deformation occurred as 1.868 mm at 0 degree fiber angle in graphite fiber epoxy matrix sandwich composite plate
- The highest deformation occurred as 2.141 mm at 0 degree fiber angle in aramid fiber epoxy matrix sandwich composite plate

- The lowest deformation occurred as 0.676 mm at 90 degree fiber angle in graphite fiber epoxy matrix sandwich composite plate

- The lowest deformation occurred as 1.011 mm at 90 degree fiber angle in aramid fiber epoxy matrix sandwich composite plate

- Deformation does not change according to fiber angle in the glass fiber epoxy matrix sandwich composite plate.

The fiber angles of aramid fiber epoxy matrix sandwich composite plate, graphite fiber epoxy matrix sandwich composite plate increase under in-plane load, the deformation values decrease, while the deformation values for glass fiber epoxy matrix sandwich composite plate remain constant at different fiber angles. According to analysis results, for aramid fiber epoxy matrix sandwich composite plate, graphite fiber epoxy matrix sandwich composite plate when maximum material strength is required in the analyzed design, an angle of 90 degrees should be applied to the fibers. If glass fiber epoxy matrix sandwich composite plate is desired to be used in the design, angles should not be applied to the fibers.

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Chapter 9

A REVIEW OF AUXETIC MATERIALS: PROPERTIES, CLASSIFICATIONS, MANUFACTURING AND APPLICATIONS

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1. Introduction

The appellation of Poisson's ratio is derived from Siméon Poisson, a distinguished French scholar in the fields of mathematics and physics, who first introduced the term during the initial years of the 1800s (Arago, 1854). Poisson's ratio (v) is a fundamental characteristic of materials that offers a quantitative assessment of the relationship between transverse strain and longitudinal strain. It is particularly represented as negative ratio of transverse strain to longitudinal strain, as expressed follow.

$$v = -\frac{\varepsilon_{Transverse}}{\varepsilon_{Longitudinal}} \quad (1)$$

The Poisson's ratio is expressed with a preceding minus sign to ensure that conventional materials exhibit a positive ratio. In materials possessing isotropic properties, the significance of Young's moduli (E), the shear moduli (G) and bulk moduli (K) is equally substantial to that of Poisson's ratio. The rationale behind this is the ability to define Poisson's ratio through the utilization of G and K modules (Poirier, 2000). The relation among said modules is explicated as below.

$$G = \frac{E}{2(1+v)} \quad (2)$$

$$K = \frac{E}{3(1-2v)} \quad (3)$$

By means of their combination, Poisson's ratio can be delineated as follow.

$$v = \left(\frac{3K-2G}{6K+2G}\right) \quad (4)$$

The restriction imposed by this particular formula on Poisson's ratio confines its value within the range of -1 to 0.5, specifically in the context of the $0 \leq K\ /\ G < \infty$ state (Fung, 1965). A positive value for this parameter implies lateral expansion of the material following stretching, as shown in Figure 1(a). Furthermore, it is noteworthy that a Poisson's ratio of 0.5 is indicative of materials that are incompressible. Additionally, there exist materials that demonstrate contrasting characteristics to those possessing positive Poisson's ratio. These materials exhibit a transverse expansion when subjected to tensile forces, while they tend to undergo size reduction in transverse direction when compressed, as shown in Figure 1(b) (Evans, & Alderson, 2000). Materials that manifest such behavior are endowed with negative Poisson's ratio and are known as auxetic.

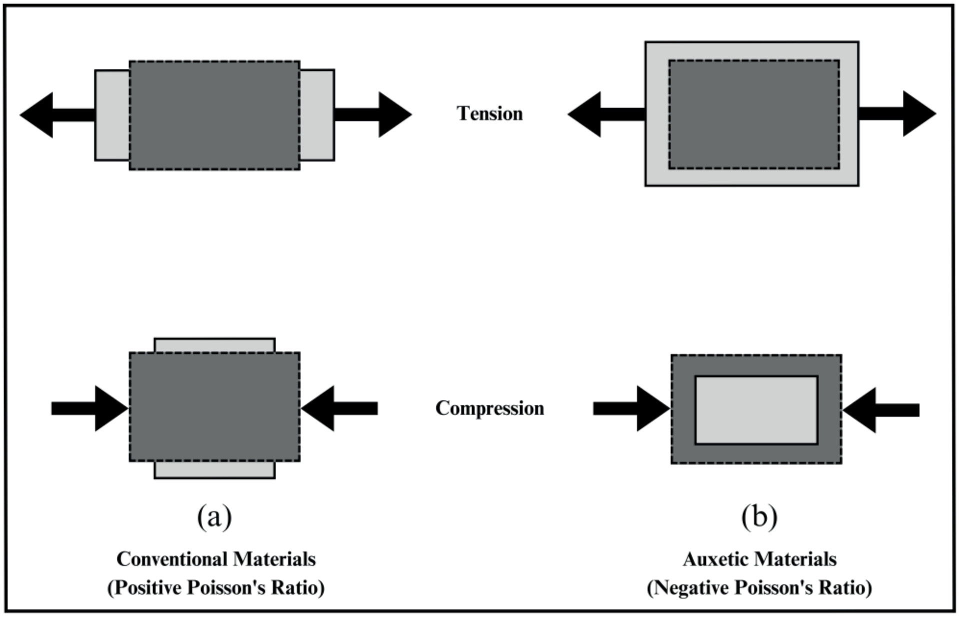

Figure 1. *Schematic diagram of deformations: (a) conventional material; (b) auxetic material.*

During the 1980s and 1990s, investigations were conducted by researchers regarding materials possessing a negative Poisson's ratio, encompassing biological tissues (Veronda, & Westmann, 1970; Williams, & Lewis, 1982) and foams (Lakes, 1987). These studies include mechanical behavior of the naturally occurring re-entrant honeycomb by Gibson et al. (1982) and foam with a negative Poisson's ratio, which was discovered by Lakes (1987). It is worth noting that Lakes did not employ the now commonly utilized term, auxetic, in his findings. In fact, the term auxetic only emerged in literature a few years following the discovery. The term "auxetic" is of Greek origin, especially derived from the word "auxetikos" and denotes a tendency to increase. Following the finding of a research done in 1991, the term "auxetic" was introduced and used as an abbreviation in order to avoid the expression of material with negative Poisson's ratio (Evans et al., 1991).

The discovery and comprehension of auxetic materials have unlocked novel possibilities for engineering applications. These range from bolstering the mechanical performance of structures to enhancing the functionality of various of products. The auxetic materials exhibit great potential for researchers, primarily due to their superior properties, which include sound absorption (Scarpa et al., 2004), shear resistance (Choi, & Lakes, 1992), synclastic behavior (McCaw, & Cuan-Urquizo, 2018), variable permeability (Alderson et al., 2000) and impact/energy absorption performance (Jiang, & Hu, 2017). By utilising these exceptional possessions, researchers aspire to revolutionize various fields such as aerospace engineering (Lira et al., 2011), biomedicine (Wu et al., 2018), military (Wang et al., 2018), sports equipment (Duncan et al., 2018), and textiles (Wang, & Hu, 2014). The auxetic materials has captivated the interest of numerous scientists in the literary world, owing to their superiority over conventional materials, their remarkable tunableness and their unique deformation patterns. To exhibit this phenomenon in the best way, Figure 2 was created, utilizing the Web of Science search engine, which shows the number of publications reaching today. As depicted in the Figure 2, auxetic materials have emerged as one of the foremost trends within the scientific community.

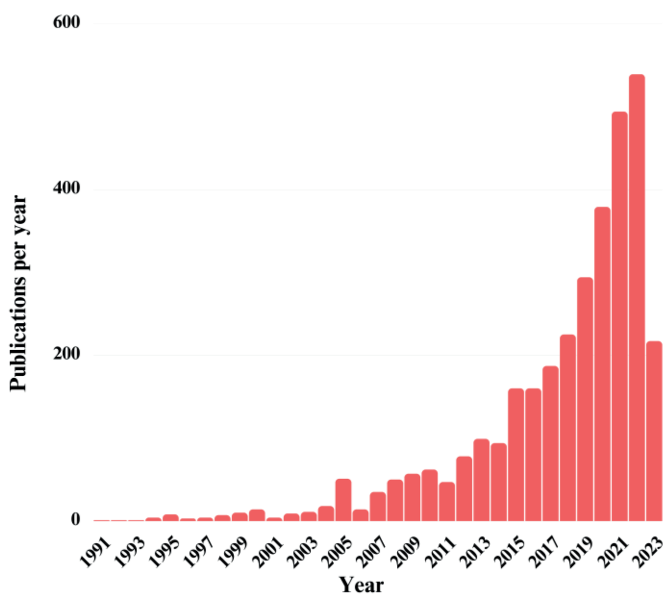

Figure 2. *Number of articles found in the Web of Science database using the term "auxetic" as a keyword.*

This paper presents a scholarly exploration of the captivating realm of auxetic materials. The main objective is to unveil the underlying mechanisms that are responsible for their remarkable properties and to delve into the scientific intricacies behind their structures. Furthermore, an exhaustive investigation is conducted into the diverse industries that actively harness the immense potential of auxetics, from aerospace to biomedicine and beyond. By comprehensively understanding the boundless potential of these materials, a revolutionary future can be envisaged, whereby designs are no longer constrained by conventional limitations. This paper is comprised of several sections, each containing significant information pertaining to the topic at hand.

2. Properties and Classification of Auxetic Materials

Auxetic materials possess a unique properties that distinguishes them from conventional materials. This counterintuitive behavior gives them a set of distinctive mechanical properties that make them highly attractive for various applications (Orhan, & Erden, 2022a). The following section outlines these fundamental properties.

Auxetic materials exhibit more resistance to shear forces compared to conventional materials (Scarpa, & Tomlin, 2000). According to the classical theory of elasticity, the elastic characteristics of isotropic materials can be delineated by means of Equation 2. Examining the aforementioned equation, it is apparent that a decrease in the Poisson's ratio yields an increase in the value of shear moduli (G). As Poisson's ratio approaches -1, the shear moduli (G) tend to infinity so that the auxetic materials almost show no shear deformation.

When conventional materials are subjected to out-of-plane bending moment, they demonstrate a saddle-shape deformation, as shown in Figure 3(a). In contrast, auxetic structures exhibit a dome-shape curvature, a behavior commonly referred to as synclasticity, as shown in Figure 3(b). This unique characteristic enables the effective grasping of domed surfaces utilized in various applications (Alderson et al., 2010a).

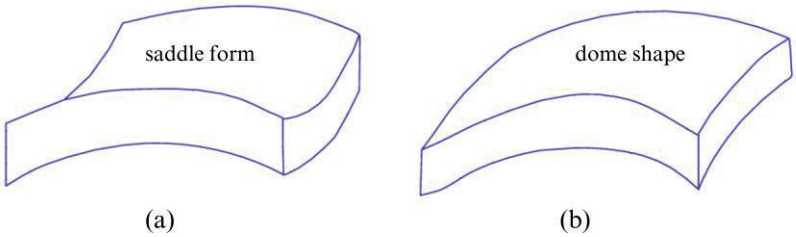

Figure 3. *Out-of-plane bending deformation patterns: (a) conventional saddle form; (b) auxetic dome shape.*

Auxetic materials possess a notable attribute of energy absorption. Recent studies have explicitly stated that auxetic materials exhibit greater energy absorption and higher impact resistance in comparison to conventional materials (Chen, & Pugno, 2012; Yang et al., 2013). It is essential to comprehend the fundamental mechanisms accountable for the energy absorption behavior of auxetic materials to utilise them effectively. The energy absorption behavior of auxetic materials is closely associated with their microstructural features. The material's ability to dissipate energy during deformation is attributed to the unique arrangements and interactions of constituent elements at the microscopic level. The microstructural behavior observed in auxetic structures can also be explained by one of other feature of auxetic, which is indentation resistance (Saxena et al., 2016). Conventional materials experience expansion deformation in the direction perpendicular to the applied load. In contrast, auxetic materials generate local contraction at the load application point, resulting in increased density and resistance, as shown in Figure 4. This enhancement in the performance of auxetic structures leads to improved energy absorption ability.

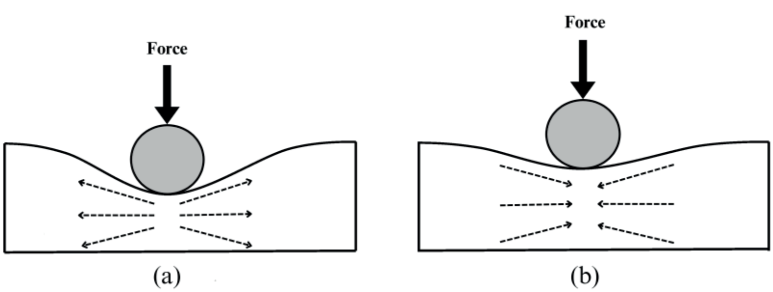

Figure 4. *Indentation resistance behavior: (a) conventional materials; (b) auxetic materials.*

Auxetic structures possess a characteristic of variable permeability owing to its porous nature. Permeability in materials describes its capacity to facilitate the movement of substances, such as fluids or gases, through its structure (Alderson et al., 2001). Typically, most materials exhibit a constant permeability irrespective of deformation. However, auxetic materials deviate from this conventional behavior by demonstrating diverse permeability patterns. When auxetic materials are subjected to tensile forces, their internal structure undergoes expansion, leading to a rise in porosity. This expansion causes the opening of previously obstructed or constricted pathways within the material, thereby facilitating fluid or gas flow. Consequently, the deformation of the auxetic material results in an increase in its permeability, thereby enabling the diffusion or transport of substances to occur more efficiently through its structure. Conversely, the internal structure of auxetic materials undergoes contraction when subjected to compression, resulting in a consequent reduction in porosity. This phenomenon leads to the closure of pathways, thereby restricting the flow of fluids or gases. As a result, compression of auxetic materials causes a decrease in permeability, ultimately impeding the diffusion or transport of substances (Attard et al., 2018). The variable permeability exhibited by auxetic materials presents a numerous potential applications. One such area is in the realm of filtration, where auxetic materials can be employed for the creation of adaptive filters that can modulate their permeability in response to externally applied forces (Alderson et al., 2007). This dynamic behavior enables these filters to effectively respond to fluctuations in flow rates and pressure differentials, thereby ensuring optimal filtration efficiency across a diverse range of conditions.

It was stated in Figure 2 that auxetic materials have a rising trend in the literature. Other reasons for such interest are that it can be found in different shapes and is geometrically and mechanically tunable. Auxetic materials can most basically be classified as natural and man-made (Orhan, & Erden, 2022b). Extending this classification further, auxetic structures can be found in four categories in the literature, which are natural, cellular, metallic, and multi-material composites (Kelkar et al., 2020). The appearance of natural auxetic materials was documented a considerable time ago. Yeganeh-Haeri et al. (1992) provided a paper on natural auxeticity in the form of α-cristobalite and silicon dioxide. Metal-based structures exhibiting auxetic characteristics are denoted as metallic auxetics. Multi-material composites, on the other hand, are structural configurations comprising of multiple auxetic materials.

Moreover, cellular auxetic materials represent another class of auxetic materials. This study comprehensively discusses the classification of cellular auxetic materials within the context of auxetic materials. A comprehensive categorization of auxetic materials is presented in Figure 5.

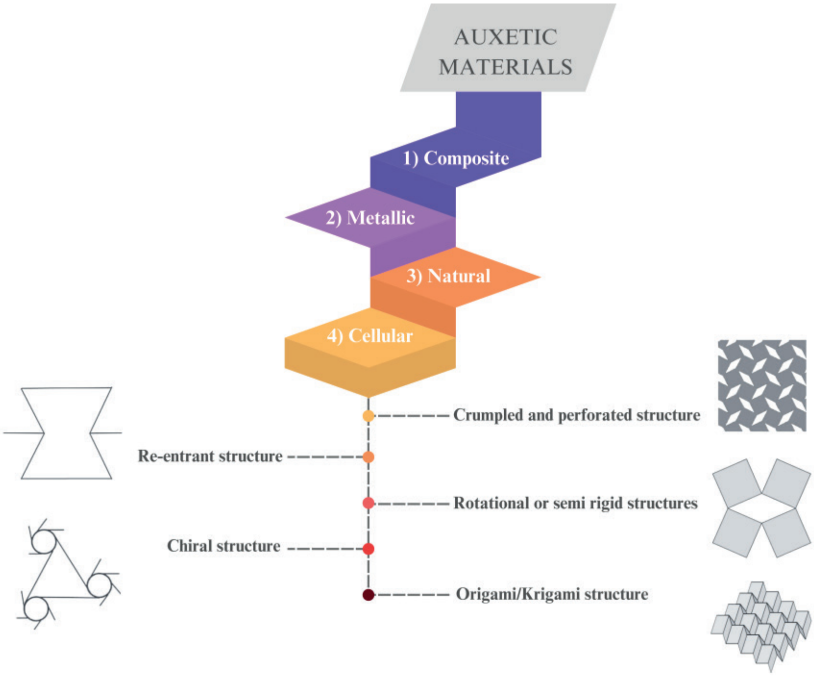

Figure 5. *Categorization of auxetic materials.*

The initial appearance of a re-entrant cellular structures was observed in the work of Gibson et al. (1982). Subsequently, an analysis of two-dimensional behavior was conducted in the study by Masters, & Evans (1996). Chen, & Fu (2017) designed a modified configuration by enhancing the 3D classical re-entrant honeycomb structure. They employed a combination of theoretical and numerical analysis to acquire a detailed comprehension of the elastic behavior of the structure and its reliance on geometric parameters, which is seen as an improved design of the re-entrant honeycomb. The new structure has been validated analytically and numerically to exhibit negative Poisson's ratio properties. The novel 3D structure has been verified to possess a superior negative Poisson ratio in comparison to a conventional re-entrant honeycomb. Rad et al. (2019) conducted a comprehensive investigation into the impact of energy absorption capacity of distinct cellular auxetic structures under quasi-static and dynamic loads on the unit cell, utilizing both experimental and numerical approaches. The re-entrant structure was preferred among the diverse structures considered, owing to its embodiment of the fundamental characteristics of auxetic material. Re-entrant structures of varying geometric parameters were simulated and compared with conventional counterparts. The findings revealed that auxetic structures werw superior to non-euxetic structures with respect to all investigated indicators of impact resistance and energy absorption, due to their remarkable ability to withstand quasi-static axial impact loads.

The initial proposition of chiral was first introduced by Kelvin (1894), and it pertained to a particular type of structure that cannot be superimposed with its mirror image. This structure consisted of a central cylinder that was encapsulated by tangentially attached ligaments. As a result of the mechanical loads experienced by the rigid ligaments, the chiral structures exhibit auxetic behavior, leading to a Poisson ratio of approximately -1 (Spadoni, & Ruzzene, 2012; Prall, & Lakes, 1997). Based on the placement of central cylinders in relation to tangential ligaments, as well as the number of ligaments present on each central cylinder, there are five prevalent types of chiral structures: hexachiral, trichiral, antitrichiral, tetrachiral, and antitetrachiral structures (Grima et al., 2008; Alderson et al., 2010b). Ma et al. (2018) conducted a study involving the design and production of four distinct chiral type cylindrical shells by employing the 3D printing method. The research involved the execution of theoretical analysis, finite element analysis, and quasi-static axial compression tests to examine the mechanical and deformation characteristics of the cylindrical shell with different chiral type cells. The findings reveal that the compressive modulus of the cylindrical shell is within 5% of the mean deviation from the analytical formulas derived from the Euler-Bernoulli beam theory. It is worth noting that chiral cylindrical shells demonstrate superior compressive modulus and strength when compared to other shell categories. Zhang et al. (2022) have proposed a novel methodology to enhance the stiffness of auxetic composites. In this study, the junction points of the ligatements in the chiral auxetic structure were modified using a circular section. The mechanical properties of the traditional and novel chiral structures produced by the additive manufacturing technique were investigated, with and without polyurethane foam filler. The uniaxial compression test was conducted, and numerical analyses were compared in terms of energy absorption capacity and auxeticity. The findings of the study demonstrate that the proposed methodology effectively enhances the mechanical properties of the chiral structure.

Crumpled auxetic sheets are generated through the application of controlled deformation to flat materials, leading to the formation of a three-dimensional structure with numerous wrinkles and folds. The utilization of crumpled structures was found to be influenced by the Japanese paper arts Kirigami and Origami. This subsequently led to the integration of said paper arts into studies containing auxetic materials, thus giving rise to a new category of auxetic materials. Perforated auxetics, on the other hand, are auxetic materials that feature regularly distributed holes or perforations throughout their structure. The introduction of these voids offers additional mechanical properties on the material, expanding its range of potential applications (Wang et al., 2020). The incorporation of perforations not only reduces material weight but also enhances its flexibility and acoustic properties. Solak, & Orhan (2022) presented a novel approach for the modification of peanut-shaped perforation of auxetic structures by means of rotating the unit cells at an angle and positioning a stiffener precisely at the centre of the peanut perforations. The numerical investigation of peanut-shaped structures was carried out in this study, revealing that the utilization of stiffeners can facilitate the simultaneous achievement of high auxetic behaviour and high stiffness. In another study, Solak, & Orhan (2023) conducted an analysis on the confinement effects of peanut-shaped perforations possessing a negative Poisson's ratio in scenarios where concrete is used as the filler material. The findings of the study demonstrated that auxetic structures with perforations exhibited greater confinement properties compared to their non-auxetic counterparts, despite having identical porosity levels.

A distinct type of auxetic structures is the rotational or semi-rigid structure. These structures obtain their exceptional properties from their intricate geometric arrangement. They are commonly composed of repeating unit cells or modules that connect in specific ways, forming a larger pattern. This arrangement permits the distribution of stress or strain through the structure, which results in the remarkable auxetic behavior (Grima, & Evans, 2000). Examples of these structures include rotating squares (Li et al., 2002), rotating rectangles (Grima et al., 2005), and rotating triangles (Chetcuti et al, 2014).

3. Fabrication Techniques and Applications of Auxetic Materials

Auxetic materials have become increasingly popular due to their advantages. This has led to an increase in their implementation across various domains. As the employment of these materials continues to expand, intricate geometric parameters have been incorporated into their designs to meet diverse requirements. Many production techniques have been proposed to physically manifest these intricately designed auxetic structures. This section will first delve into these production techniques and subsequently shed light on the various applications of auxetic materials.

The utilization of additive manufacturing, also recognized as 3D printing, has significantly revolutionized the manufacturing industry by providing the means to creat intricate structures with unprecedented design flexibility. An intriguing application of this technology is the fabrication of auxetic materials (Joseph et al., 2021). The process of additive manufacturing presents an ideal platform for creating auxetic structures. By employing various 3D printing processes, such as fused deposition modeling (FDM) (Bikas et al., 2016), selective laser sintering (SLS) (Kruth et al., 2005), or stereolithography (SLA) (Choi et al., 2011), Polyjet (Liu, & Zhang, 2018), selective electron beam melting (SEBM) (Murr et al., 2012), it is possible to precisely control the deposition of material layer by layer, enabling the creation of intricate geometries that exhibit auxetic behavior (Wallbanks et al., 2021). In conclusion, additive manufacturing has proven to be an effective means of creating auxetic structures. By utilising the design freedom and layer-by-layer fabrication capabilities of 3D printing, engineers and researchers can unlock the full potential of auxetic structures, leading to novel materials with exceptional mechanical properties and enabling exciting advancements across various industries.

In addition to additive manufacturing, a number of conventional techniques have been modified by researchers for the production of auxetic structures, and the effectiveness of these approaches has been demonstrated. The utilization of molding technique is frequently employed during the fabrication of composite structures. Li et al. (2023) conducted an experimental and numerical investigation of the mechanical properties of metallic stacked Miura-origami, whereby the production of the structure employed the hot molding method. Metallic stacked Miura-origami is generated through the stacking and interconnection of origami layers that exhibit alternating geometries between successive layers. Rotary laser cutting technique for cylinder and square tubular is preferred in the literature. Doudaran et al. (2022) conducted a study to investigate the energy absorption capabilities of metal tubular structures, both with and without foam, incorporating anti-tetrachiral, reentrant, honeycomb, and arrowhead geometries under quasi-static conditions. It is noteworthy that all specimens were generated through employment of the laser cutting technique. Vacuum casting represents one of the production methods employed in the creation of structures possessing auxetic properties. These structures are utilized in the field of biomechanics and are intended to remain within the human body for a long time. In their study, Ali et al. (2014) conducted an analysis of the surface morphology of the auxetic stent utilizing the rotating squares geometry. The stent's tubular form was achieved through the employment of laser cutting, followed by the creation of the auxetic film. The ultimate image of the stent was attained through the implementation of the vacuum casting method, using auxetic film. The mechanical behavior of the resulting stent was evaluated both through numerical and experimental. The literature has been examined to provide a summary of the studies conducted pertaining to both additive manufacturing and conventional methods, as presented in Table 1.

Table 1. *Summary of manufacturing techniques.*

Manufacturing technology	Auxetic structure	References
Polyjet	Re-entrand and anti-tetrachiral	Günaydın et al. (2022)
Polyjet	Re-entrant	Zorzetto et al. (2017)
FDM	Re-entrant	Vyavahare, & Kumar (2021)
FDM	Re-entrant, anti-tetra chiral and arrowhead	Najafi et al. (2022)
FDM	3-pointed star-shaped	Chen, & Lee (2022)
SLS	Tetrachiral and anti-tetrachiral	Geng et al. (2019)
SLS	Re-entrant	Yao et al. (2023)
SLA	Antichiral-reentrant	Ruan et al. (2018)
SEBM	Chiral	Novak et al. (2020)
SEBM	13th eigenmode of regular cubic	Warmuth et al. (2016)
Mold casting	Re-entrant	Jiang et el. (2018)
Rotary laser cutting	Elliptic	Logakannan et al. (2022)
Vacuum casting	Tetrachiral/hexachiral honeycomb	Abramovitch et al. (2010)

The utilization of materials possessing a negative Poisson's ratio has experienced a rapid acceleration subsequent to the integration of advanced manufacturing techniques with auxetic structures. The exceptional and appealing characteristics of auxetic structures are capable of satisfying present-day demands. These favorable facts have formed a classification denominated as the applications of auxetic structures. The application domains, which are frequently encountered in literature, are detailed below.

In the realm of biomedical, auxetic materials are employed in a variety of domains. A notable implementation involves the creation of stents, annuloplasty rings, implants and drug delivery systems. Auxetic stents possess the ability to expand when inserted into a blood vessel, which facilitates placement and diminishes the likelihood of complications. Furthermore, auxetic materials can be utilized in the production of wound dressings to create adaptive and conformable bandages that provide superior fit and enhance the healing process. A novel coronary stent possessing auxetic characteristics was introduced by Amin et al. (2015). It is stated that this auxetic stent, featuring inherent anisotropic mechanical properties, will exhibit favorable adhesion to the arterial wall. In this study, novel auxetic stent did not demonstrate any degree of shortening, thus enabling it to expand both radially and longitudinally and thereby resolving the issue of stent displacement. Mir et al. (2017) conducted a macro-scale study utilizing the rotating square unit cell. The polymer casting technique was employed to produce the auxetic structure, with ABS being chosen as the mold material. The study demonstrated that this model improves wound healing and is beneficial for tunable drug delivery applications.

In addition to their biomedical applications, incorporating auxetic materials into sports equipment, such as gloves and helmets, has demonstrated their versatility. The utilization of these materials has yielded improved levels of conformability, thereby enhancing support and safeguarding athletes against the impact of external forces. The high energy absorption ability of auxetic materials is a key factor contributing to their effectiveness in this regard. Foster et al. (2018) demonstrated the efficacy of utilizing auxetic foam as a comfort layer in sports helmets. This innovation resulted in a decreased intensity of linear effects when compared to conventional counterparts. These findings shed light on the potential for further advancements within the realm of protective equipment, specifically in terms of mitigating post-impact transmitted acceleration levels. Faraci et al. (2021) conducted a study aimed to evaluate the efficacy of layered thin plates, which may have implications for the development of wearable protective devices. In particular, two distinct three-dimensional unit cells, namely the conventional and re-entrant honeycomb, were examined in detail and their dynamic characteristics were compared with their two-dimensional counterparts. Additionally, a novel lightweight solution featuring a sandwich structure with an auxetic core was proposed as a potential means of enhancing the protective capabilities of facial protective devices. The authors concluded that the proposed approach outperforms the conventional method in terms of impact resistance.

Auxetic materials have made significant inroads into the textile industry, fundamentally transforming the design and functionality of fabrics. The incorporation of auxetic structures into fabrics has enabled them to exhibit exceptional stretchability in various directions, which in turn, has substantially enhancing comfort and freedom of movement. The utilization of such materials has proved particularly advantageous in the development of sportswear, compression garments, and flexible clothing, wherein elasticity and durability represent vital attributes. Miller et al. (2009) conducted a study on the utilization of a novel double-stranded yarn that has demonstrated auxetic properties, as well as an auxetic composite produced from this yarn in a woven textile structure. This marks the first instance of a composite displaying auxetic behavior through the use of naturally auxetic yarns. Furthermore, both the yarn and composite were manufactured through standard techniques, thus making them potentially valuable for a diverse array of engineering applications. Glazzard, & Breedona (2014) introduced a novel approach to the design of auxetic textiles through the utilization of knit design techniques. The primary objective of their study was to develop weft-knitted fabrics that demonstrate auxetic properties, characterized by expansion in either the X- or Y-axis. The investigation aimed not only to address the functional aspects of auxetic fabrics but also their aesthetic, tactile, and subjective design qualities. The authors demonstrated that conventional textile machinery and design processes can be employed to produce auxetic materials.

In addition to the aforementioned applications, the scope of application areas for auxetic structures is expandable. With the emergence of novel production techniques and advancements in existing techniques, the applicability of these structures is augmented. Table 2 presents comprehensive application areas of auxetic structures as documented in the literature.

Table 2. *Summary of existing applications (Prawoto, 2012).*

Field	Applications
Aerospace	Vanes for engine, thermal protection, aircraft nose-cones, wing panel, vibration absorber
Automotive	Bumper, cushion, thermal protection, sounds and vibration absorber parts, fastener
Biomedical	Bandage, wound pressure pad, dental floss, artificial blood vessel, artificial skin, drug-release unit, ligament anchors, surgical implants
Composite	Fibre reinforcement
Military	Helmet, bullet proof vest, knee pad, glove, protective gear
Sensors/actuators	Hydrophone, piezoelectric devices, various sensors
Textile	Fibres, functional fabric, colour-change straps or fabrics, threads

4. Concluding Remarks

In this review, the captivating realm of auxetic materials is explored in terms of their unique mechanical properties, areas of application, and categorization. It must be emphasized that notwithstanding the authors' attempts to provide a comprehensive overview of the literature, certain investigations pertaining to auxetic materials were included due to space limitation. Through our investigation, it was revealed that auxetic materials exhibit exceptional characteristics which set them apart from conventional materials. To illustrate, their negative Poisson's ratio provide superior impact resistance, shear resistance, synclastic behavior and variable permeability. These properties make auxetic materials highly compelling for employment in domains such as protective equipment, shock-absorbing coatings, adaptable electronics, textile application and medicinal implements. Additionally, our investigation into various forms of auxetic structures has uncovered a vast array of potential design options. From the implementation of re-entrant geometries to the utilization of Origami/Kirigami-inspired unit cells, the authors demonstrated their capability to customize auxetic behavior to meet specific application requirements. It is believed that this adaptability will present novel opportunities for the advancement of auxetic materials possessing innovative and distinct properties. Despite the vast potential of auxetic materials, there exist various challenges and limitations. The manufacturing processes for auxetic structures can be intricate and expensive, necessitating precise control of material properties and complex fabrication techniques. The production restrictions for auxetic materials result in faulty manufacturing. The mechanical properties of deformed auxetic structures still arouse curiosity in the present day. Further research ought to be conducted on auxetic structures with deformations that occur during production so that real-time applications can be consistently designed. Furthermore, the mechanical behavior of auxetic materials may be susceptible to factors such as strain rates, temperature, and loading conditions, necessitating additional research to better comprehend and optimize their performance. It is useful to express that it is crucial to continuously engage in research and development within the realm of auxetic materials. Further investigations into novel production methodologies and characterization techniques is necessary to overcome present obstacles and unlock the complete potential of auxetic materials. Additionally, investigating the integration of auxetic materials with other advanced technologies, such as additive manufacturing, nanotechnology, and smart materials, presents substantial potential for extending the scope of application areas and fostering synergetic material systems.

As a consequence, auxetic materials represent an exceptional category of materials possessing remarkable mechanical characteristics and immense potential for innovation. Their ability to adapt and respond to changing conditions offers exciting possibilities for a wide range of applications across numerous sectors. We can pave the way for a future in which auxetic materials play a revolutionary role in engineering, manufacturing, and beyond by dealing with present challenges and expanding existing knowledge.

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Chapter 10

UNMANNED UNDERWATER VEHICLE TECHNOLOGIES

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1. Introduction

"Unmanned Underwater Vehicles" (UUV) are robotic systems designed to perform certain tasks underwater and They are vehicles that are controlled by an operator from land, boat or a diver in water. With the technological developments in the last 20-30 years, underwater vehicles are also developing more and more and they increasingly being used in many fields. Underwater Unmanned platforms are more preferred for people in harsh working environments and dangerous jobs.

Figure 1: Remote Operating Vehicle *(ROV)(3D model)[1]*

In fact, UUV technology has not yet reached its potential. This technology has been overshadowed by flying drones for many years. The working conditions of UUVs at sea can be divided into three categories. These are, close the sea surface, medium depths and near the seafloor depths. The main challenge in the design of underwater vehicles is adapting their maneuverability and capabilities to different operating conditions [2]. In an underwater vehicle to be designed to determine system level requirements, different engineering disciplines must be in communication with each other. The most basic engineering area that can be evaluated for underwater vehicle system is hydrodynamics. The hydrodynamic design is determined according to the desired characteristics of the underwater vehicle, and it is customized and improved.

Figure 2: AUV(Autonomous Underwater Vehicle) [3]

Since the production of ISAAs is expensive, it should be done in detail while making the project plan. That's why their controls, whether wired or wireless, need to be perfect. For this reason, first of all, it is necessary to create the correct behavior functions on a correct modeling for the design.. There are some key points in UUV technology, some of which are; Software, Navigation, Autonomous, wireless communication. In this study, We will explain the details of these issues.

It is not known exactly who made the first unmanned underwater vehicles in history. One of the earliest recorded examples is the "PUV (Programmed Underwater Vehicle)" vehicle developed by Luppis-Whitehead Automobile in Austria in 1864. This vehicle is a torpedo-shaped underwater vehicle controlled by a remote control. The design, which is more similar to the widely used designs today, is the tool called Poodle, which was first designed by Dimitri Rebikoff in 1953.

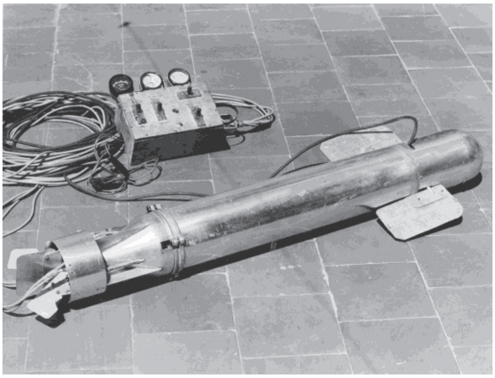

***Figure* 3:** Poodle tool designed by Dimitri Rebikoff [4]

One of the important studies in this field was carried out by the British Royal Navy and the US Navy. These vehicles, which can be classified as non-autonomous and remotely controlled, were generally used for mine and explosive destruction and clearance in the first years. The "CURV (Cable Controlled Underwater Recovery Vehicle)" vehicle of the US Navy pulled the atomic bomb from under the sea, which was lost after a plane crash in Spain in 1966. Remote-controlled underwater vehicles rescued the crew of the submarine, which sank in Ireland in 1973, when they had only a few minutes of oxygen left. These examples are the most important examples of how useful it can be operationally.

2) Usage Areas of Unmanned Underwater Vehicles

Modern ROVs are much smarter and more functional than large mass vehicles of the past. They specialize in different fields according to their usage areas. Modern ROVs are designed according to different features from each other. Different designs are made according to the depth, working area and function where they will work shown in Table 1.

Table 1 : *UUV Usage Areas*

MILITARY	SCIENTIFIC	INDUSTRIAL	CIVILIAN
Observing	Mining	Fishing	Hoby
Defence	Ocean Biology	Photography	Diving
Mine clearing	Scientific discovery	Energy Facility Studies	Treasure hunting
Search and Rescue	Environmental Activities	Film and Documentary	Sport
Weapon Tests	Mapping	Infrastructure	Competition
Military ship activities		Port Services	Hunting

While some Underwater drones are produced for sports and entertainment purposes, some are produced for professional purposes. A wide variety of models are produced in the world and the marketing range is gradually expanding. All countries that have a sea coast in the world are trying to make and develop their own ISAAs. As a result of these studies, different components are produced and developed strategically.

Military Rov technology will have a very important place in the future. In operations, drones have saved a lot of human lives. The smartening of weapon systems will also change the structure of wars. It is inevitable that drones will replace humans in military missions. Threats to security are often hidden in underwater locations, Esther as discarded evidence, contraband travelling on ships, or explosives placed to cause destruction. A ROV gives a safe view of threats and evidence that is hidden beneath the waves, without jeopardizing diver's safety.

Figure 4: *Military ROV* [5]

Underwater sports activities are very special areas for usage of ISAAs. The "Turkish Underwater Federation-CMAS Freediving Championship" that held in 2016 to 2022 in Turkey's Antalya province, Kaş district is one of the closest examples. Spearfishing Championships, Underwater Hockey, Underwater Rugby etc. competitions can become more enjoyable and famous thanks to these machines.

Figure 5: *TSSF CMAS 4 th World Freediving Championships 2021/ Antalya-Kaş [6]*

2.1) Classification Of Underwater Vehicles

UUVs are evaluated in two main groups: Cable Controlled and Wireless-Autonomous. The cable-controlled one is called “ROV (Remote Operating Vehicle)” and the autonomous one is called “AUV (Atonomus Underwater Vehicle)”.

UUV	Unmanned Underwater Vehicle→	**İSA**	İnsansız Sualtı Aracı
ROV	Remotely Operated Vehicle→	**KKSA**	Kablo Kumandalı Sualtı Aracı
AUV	Autonomous Underwater Vehicle→	**OSA**	Otonom Sualtı Aracı
HUV	Hybrid Underwater Vehicle→	**HSA**	Hibrit Sualtı Aracı

Table 2: *Classification and identification of Underwater Vehicles*

2.1.1) ROV (Remotely Operated Vehicle)

By definition, it is an underwater robot that is remotely controlled by an operator and performs tasks for different purposes. A ROV system; In addition to the vehicle, it consists of the operator controlling the vehicle, the equipment providing the control, the cable connecting the vehicle to the ship and the crane mechanisms that enable the vehicle to be pulled up.

ROVs are equipped with many sensors, cameras, sonar, etc. Components can be added and become tools that perform very complex tasks. ROVs can overcome the constraints and dangers of manned dives, which are limited to 250 meters. It can do very difficult construction and maintenance works at depths up to 3000 meters. Mini ROVs with a weight of 3-15 kg work in narrow places underwater.

2.1.2) AUV (Autonomous Underwater Vehicle)

The biggest advantage of AUVs is that they can move using their own navigation systems and power units without the cables that pose many problems. As AUVs are autonomous/semi-autonomous and have their own power source, they can perform planned missions on pre-planned routes.In addition, they are equipped to continue their activities in unforeseen situations or in cases where communication is interrupted during the task.

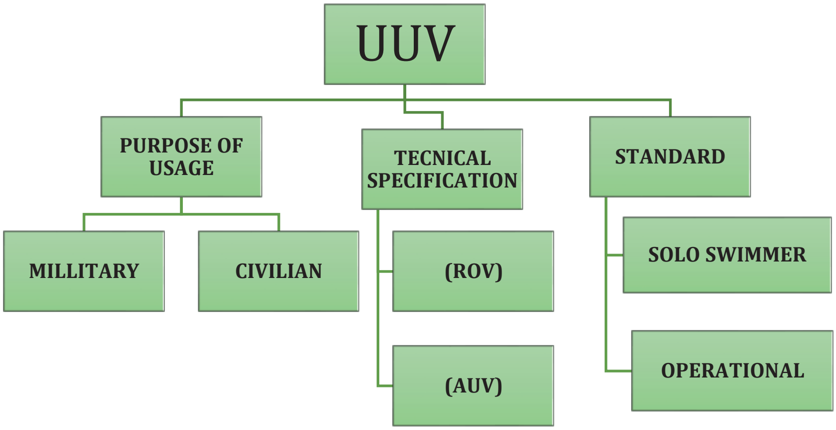

Table 3: *Grouping of Underwater Vehicles*

3) Physical Effects of Under Water

The effect of forces applied to an object in a liquid depends on factors such as the physical design of that object, weight, density, volume, velocity. While designing the vehicles that will operate under water, the calculation of hydrodynamic forces should be made for the desired range and diving depth. Since the pressure will increase as you go deeper under water, it must be made of pressure-resistant material. In order to reduce the effect of drag force, the projection area should be reduced. Therefore, one of the most used design forms in underwater vehicles is the torpedo design.[7]

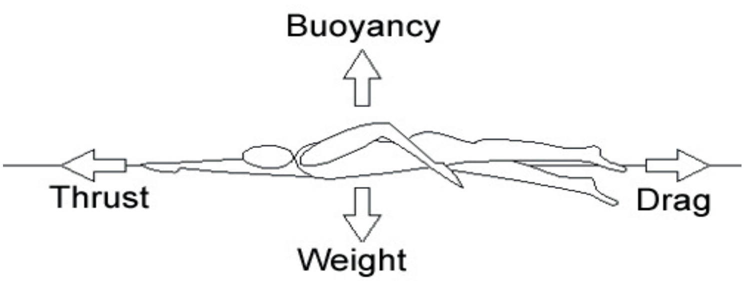

Figure 6: Hydrodynamic Forces [8]

3.1) Lifting Force

Any substance placed in a liquid is pushed upwards with a force equal to the weight of the liquid it displaces. this is called "buoyancy", "buoyancy of water" or "Archimedes' principle". The object will start to float with the effect of the thrust force arising from the density differences. g: Gravitational Acceleration (m/s2), V: Volume (m^3), ρ: Intensity(kg/m^3), Fk: Lifting Force (N) Eq. 1

$$F_k = P_s \times V \times g \tag{1}$$

3.2) Weight

It is defined as a force acting on an object by gravity. A downward gravitational force will be applied to all objects on Earth, no matter which way the object is going underwater. There may be other forces causing the object to accelerate, but the force of gravity is always present. The basic unit of mass is called the kilogram (kg) and is a quantity related to the amount or energy of matter. W : Weight (N) , g : Gravitational Acceleration (m/s2), m : Mass (kg) Eq. 2

$$W = g \times m \tag{2}$$

3.3) Drag Force

In fluid mechanics, drag is a force acting opposite to the motion of an object moving in a fluid. It has the opposite effect against forward motion. This has a negative effect on underwater vehicles. In vehicles equipped with an engine or other power tool, this force is suppressed by the thrust and the vehicle can move. [9] It is proportional to the square of the speed. If the underwater vehicle's speed increases, the drag force acting on the vehicle also increases. As we mentioned before, the drag force increases as the projection area increases. FD : Drag Force (N), Cd : Drag coefficient, v : Speed (m/s), Projection area (A) Eq. 3

$$F_d = C_d \times p \times \frac{V^2}{2} \times A \tag{3}$$

3.4) Thrust Force

Thrust Force is the force required for an unmanned underwater vehicle to move in order to overcome the opposite force. In horizontal movements, thrust force is generally obtained with propeller engines. In some vehicles, there is no need for movement in the horizontal axis due to the task, and most of the time, only weight is sufficient in these vehicles.

3.5) Disadvantages of Underwater

When designing "land unmanned vehicles", the terrain details are calculated. In aircraft, the wind effect is calculated. The disadvantages of underwater should also be considered in the design of vehicles operating under water. The atmospheric pressure, which is 1 at sea level, increases by 1 Atm every 10 meters as you go deeper. While producing UUV, a material that can resist pressure should be selected. Devices should be manufactured to minimize this pressure. Some of the disadvantages that will occur on underwater vehicles are as follows:

- Depending on the duration of use, the damage caused by salt and pressure on the vehicle under the sea increases.
- Wave movements in the sea create perturbations.
- The electromagnetic spectrum of sea water and it behaves to a certain extent. For this reason, communication problems are an important cause of problems that occur in vehicles with wireless control.
- Animals under the sea.

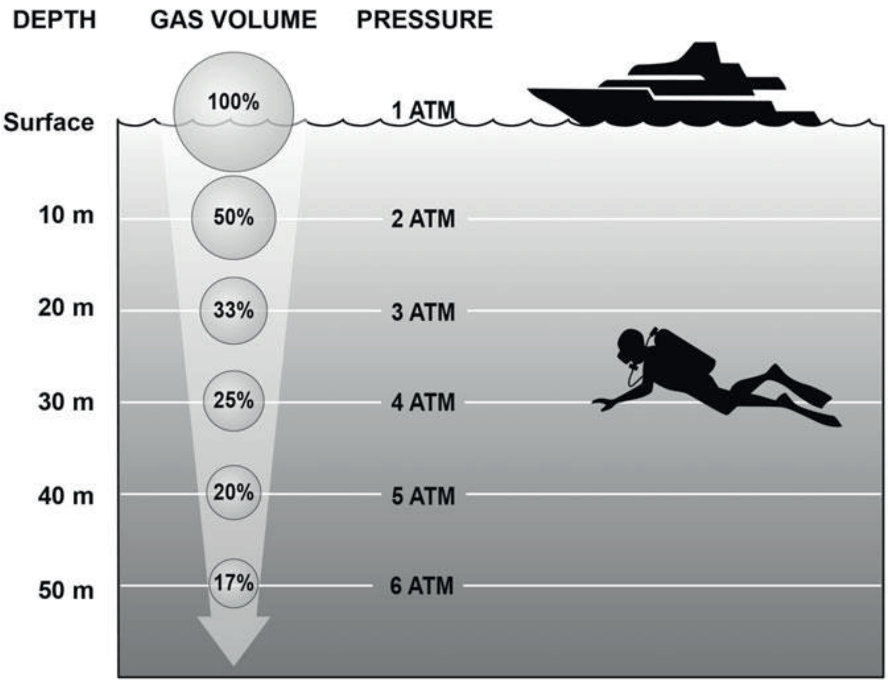

Figure 7: *Deep And Pressure[10]*

4) Design of Unmanned Underwater Vehicles

All the working parts of a UUV, from launching to mission completion, are part of the design. The design should serve the mission of the vehicle in every aspect. It is more correct to make the plan flexible so that changes can be made in the design according to the advantages and disadvantages in the plan. The design of the system is basically divided into two parts. The first is physical design. Material selection, mechanical components, electronic components are included in this group. The second part is the control and software part made according to autonomous or command control. The main components of the UUVs are:

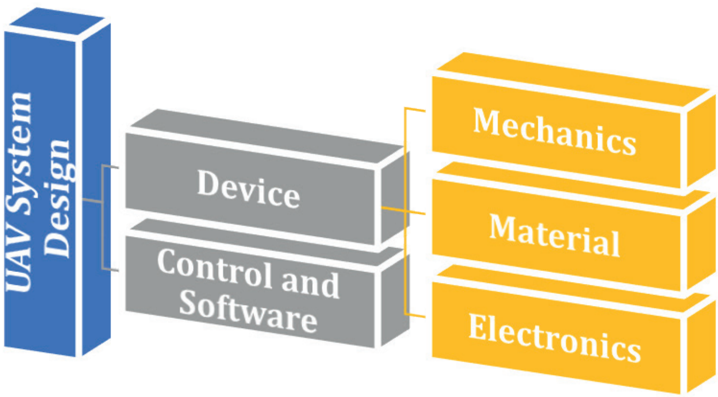

Table 4 : *Design Parts*

4.1) Hull:

Since the diving depth is related to the pressure, the hull should be designed in accordance with the mission. In vehicles that are intended to be used in deeper missions, aluminum composites added to the skeleton or polyurethane derivatives for sealing purposes are preferred.

4.2) Mechanical Parts

Mechanical parts in UUVs consist of many units that increase operational capability such as sleeving, cables, robot arm and wings. Reel, Winch system: It consists of winches and rollers that allow the ROV to be released deep and to rise to the water surface again. This mechanism used in ROVs is controlled from the console on the ship or on land. The device is used in almost all ships. [11]

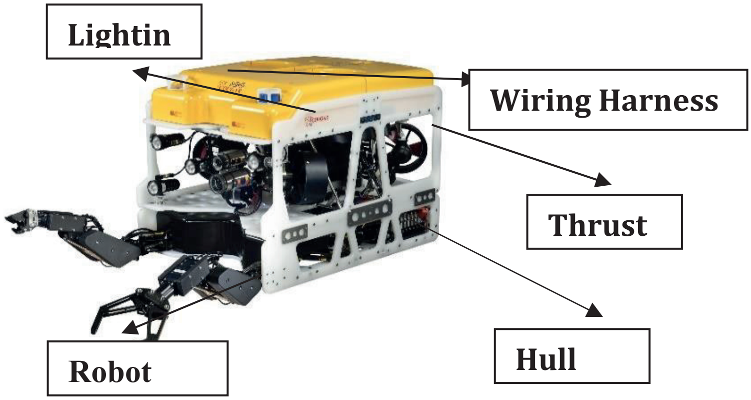

Figure 8: *ROV Design Example[12]*

- **Cable system:** These are the cables carrying the electrical load. Extra sheathed underwater cables are preferred so that these cables can carry the weight of the underwater vehicle. It is not used in autonomous vehicles.
- **Robot Arms:** Operational arms designed for different tasks can be used in ROVs. Mechanical feet are used to move by clinging to the seabed like an octopus. Mechanical arms are used for purposes such as mine clearance, search and rescue, dock repair, scientific activities.
- **Robot Wings**: In underwater vehicles, which are mostly required to move horizontally, the wings work according to the Bernoulli principle and give direction to the vehicle. According to this principle, where the fluid velocity is higher, the pressure will be higher than where the liquid velocity is slower. Vehicles traveling with wing control are used in two ways. The first is the vehicles that can travel horizontally, just like airplanes, with the thrust created by an independent engine. The second is vehicles that move vertically with the force of gravity and the pulling force of the crane.

4.3) Electronics

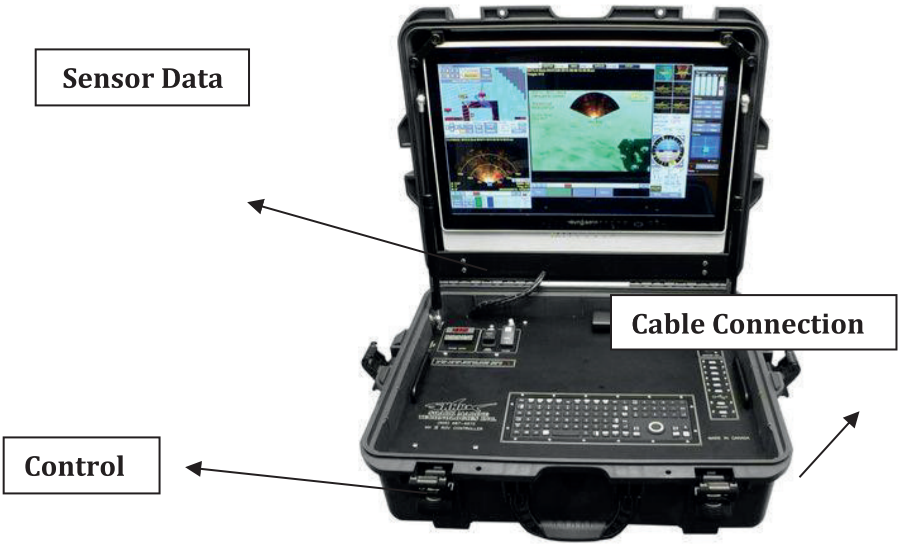

Figure 9 *:Control panel of an UUV[13]*

- **Control-communication:** The engines, wings, sensors, camera and lighting and electronic components used in the underwater vehicle are used to be controlled autonomously or by the operator. Wireless communication is used because wired communication is not possible in AUVs.
- **Motors:** DC motors are preferred in underwater drones. Direct current is current with constant direction and magnitude. DC source is obtained from sources such as batteries in drones. DC motors work according to the principle that the fixed magnetic field created in the stator pushes and attracts the fixed magnetic field created in the rotor[14]. DC motors have high torque and their speed can be adjusted. When it is desired to change the direction of rotation, the poles of the voltage applied to the rotor are changed.. AUVs usually have 1 or 2 engines, while ROVs have at least 4 engines running vertically and horizontally.

Figure 10: ROV Traction Motor Example [15]

- **Power source:** In addition to advanced lithium-ion batteries, silver oxide-zinc batteries and PEM-HYP hydrogen fuel cells can be used in İSAAs. Of these, lithium-ion based batteries are the most known and used Technologies. At first, aluminum-based semi-fuel cells were used only in large WAPS, later on, new types of hydrogen fuel cells were used because they caused environmental pollution. It is preferred to be used in unmanned underwater systems operating for a long time. Hydrogen, which is necessary for obtaining energy, can be stored in small-volume cartridges. These batteries produce low emissions, and are also a preferred power source for such vehicles, thanks to their quiet and modular structure. Unit price expensiveness is a disadvantage. Silver Oxide-Zinc Batteries are generally used in emergency situations. Very high power can be obtained in a very short time. They have a high amount of energy and the highest power output per unit volume. They are mostly used in high energy applications such as satellites, military aircraft, submarines.

Figure 11: *ROV Battery [16]*

- **Lighting:** The effect of sunlight decreases under water, especially as you go down to deep waters. It is used to assist in underwater activities and to prevent underwater hazards.

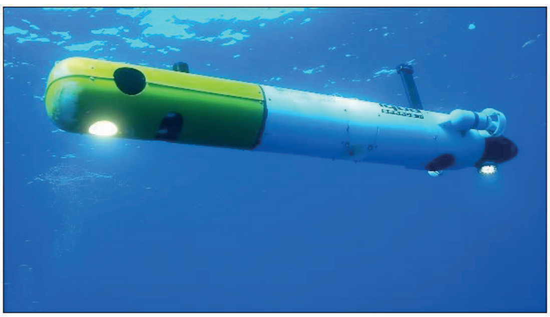

Figure 12: *ROV Lighting [17]*

4.4)Software

It is one of the most important elements necessary to ensure the control, navigation and communication of the underwater vehicle.

- A comprehensive algorithm should be created in order for different sensor units to work simultaneously and for the system to produce fast responses.
- While PIC, C, ASM type software are used in the circuits, the main core code can be written with the help of more advanced platforms based on programming languages such as C# / Java.

5) Design and Manufacturing Studies in Turkey

The most talked about underwater vehicle project in Turkey was the 'Wattozz' project, which resembles a stingray fish belonging to the Albayraklar Defense Industry company. However, although the studies in this field in Turkey do not attract the attention of the media, the projects started much earlier. Universities, government agencies, defense industry and other companies working on underwater vehicles in our country are as follows:

- Firstly, vehicles procured from abroad in the 1990s began to be used in the mine search fleet of the navy. In our country, the design and production of Domestic UAVs started at TÜBİTAK and some universities. In the private sector, it started in a few companies with the support of SSM.
- ULISAR is the Multi-Purpose National Unmanned Underwater Vehicle developed by the Middle East Technical University with the support of TUBITAK. It is a lightweight ROV that is intended to dive up to 100 m and is controlled via an acoustic link. It is the first important step in this regard in Turkey.[18]
- National PAP ROV Device Development Project supported by TÜBİTAK 1007 program.
- The autonomous ITU-AUVTECH underwater vehicle developed by ITU became a semi-finalist in the 2013 World Autonomous Underwater Vehicle Competition held in San Diego.[19]

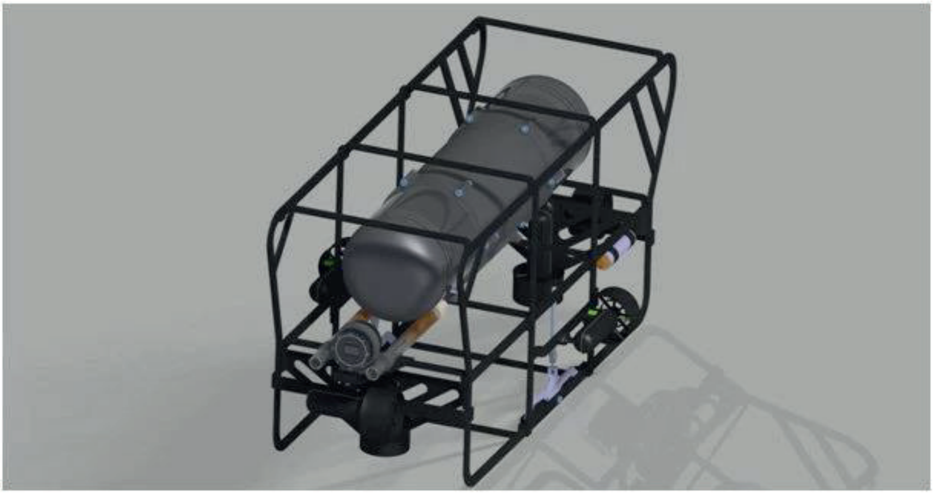

Figure 13: *ITU-AUVTECH [20]*

- METU designed the SAGA project in Teknokent and realized one of the first applications in our country. This micro ROV is still in trials in different civilian applications.
- Domestic production projects of underwater vehicles are still in progress, with the condition of national design. Some National ROVs have been successfully completed and AUV production is still ongoing. ASELSAN started to develop an AUV called 'Octopus' in 2010. “Diver”, another unmanned underwater vehicle developed by ASELSAN, is currently the only domestically produced model in its class. This model was designed to meet the needs of the Turkish Army Forces.

Figure 13: *Submersible Drone (Aselsan)* [21]

- GATE Elektronik is the leading company in our country in studies on this subject. The summary of the work is as follows;
    - A- Deep Sea Reconnaissance (Military) AUV.
    - B-Gallibolu ROV: Business Class Remotely Controlled Underwater Vehicle. It can successfully perform applications such as submarine rescue, wreck removal, seabed examination, observation and sample collection.
    - C-GMK AUV – General Purpose: GMK can be quickly and easily integrated into any platform. It has low maintenance requirements, modular structure and ease of use.
    - PAP ROV – Military ROV-Çanakkale SSR: ÇANAKKALE SSR is an underwater vehicle with remote control, minesweeping and mine hunting systems.
    - E-Mini ROV

***Figure 14*:** Çanakkale Underwater Mine Destruction Robot (GATE Electronic)[22]

6) Global Important Companies in This Technology

“Underwater Unmanned Vehicle technology” is a technology whose market share is increasing. Firms investing in this field are increasing day by day. Military, hobby, industrial etc. Due to the demands, models with new technologies are manufactured. Some famous companies in this field are:

6.1) Diveye

Diveye idea was born in 2014 in Michal’s head during freediving training in Kho Thao island in Thailand. While practicing deep freediving he started wondering how to capture really deep dives of top world athletes. He started researching existing technology and found out that little has been done in this field. From the very beginning he saw great potential of robotic underwater solution in improving safety of the diver by increasing awareness of safety team on the surface. His vision started evolving. When he returned from his trip he shared the idea with friends and freedivers. Working group was established and project was started. The end result changed the freediving world forever. Diveye allowed to continous capturing of a complete dive from the surface down to the bottom plate and back. Live video from deep dives improved safety and sport attractiveness to spectators.

(a)

(b)

Figure 15: ***(a)*** *ROV Diveye [23],* ***(b)*** *TSSF CMAS 4 th World Freediving Championships 2022/ Antalya-Kaş [6]*

6.2) Chasing

Chasing-innovation technology company is a world leader in manufacturing and selling consumer grade underwater drones, industrial grade underwater robots and portable intelligent unmanned equipment. In April 2016, Chasing's headquarters was established in Shenzhen. R&D team, underwater communication, general design, electric power and propulsion systems, navigation control, etc. He has an important talent in the field. The company has reached the international first-class level in the technical field. Chasing has obtained more than 100 invention patents and won more than 100 awards in multiple countries and continues to grow.

Figure 16: *Gladius M2 Underwater Drone[24]*

6.3) Armelsan

The domestic company was established in Tuzla in 2012. ARAS-2023 diver detection sonar, the first product developed by Armelsa, has made Turkey the fourth country to produce this technology. Armelsan cooperates with Klein Marine Systems in the field of defense industry. Armelsan is also a company that manufactures products in areas such as "Business class ROV" and "Mine hunting sonar".

Figure 17: *Business Class Remote Controlled Underwater Robot(Armelsan)[25]*

6.4) Seasam

The founding team of divers and drone experts came up with the idea of an autonomous underwater drone. Talented team members such as embedded software developers, manufacturing and supply chain managers came together to turn this idea from a dream into a reality. In 2016, Notilo Plus launched the first autonomous drone in the entertainment market and caught the attention of the industry. Since then, it has proven itself in various projects such as inspections, scientific research, defense, research and recovery. The company has been acquired by Delair, the European leader of unmanned surveillance solutions.

Figure 18: *AUV (SEASAM)[26]*

7) The Future Of Unmanned Underwater Vehicles

In the future, the use of autonomous systems will increase more than controlled systems. So AUVs will become more common compared to ROVs. A second issue is the energy issue. As hydrogen fuel cells and battery technologies develop, vehicles will stay at sea much longer and their range will increase several times. Devices will be able to work in depth more easily as composite materials and advanced material technologies develop. Vehicles of different sizes can be developed for different purposes. The use of drones in Military applications, coast guards and places that may be dangerous to humans will increase. Unit prices and maintenance costs will decrease. Thanks to the development of technology, the increase of private enterprises, the increase of public investments AUVs will be able to operate in multiple fleets and each AUV in the fleet will be able to work in harmony with each other. In this way, the tenure will be shortened and the success percentage will be greatly increased. Another benefit of AUV technology in the naval field is the throw-forget weapons used in warplanes. There is a shortage of workers in companies that do things like fiber cable lines, natural gas pipelines, and dock repairs. Therefore, the service rate of UUVs will increase in these companies..

***Figure 19*:** Next Generation AUV (Marine Research) [27]

8) Conclusions

Underwater vehicles are a technology that will benefit a country with a sea coast in more than one way in different areas. There is an increasing interest in unmanned vehicle design in our country and in the world. Underwater vehicles are life-saving vehicles in terms of the tasks they undertake. In this study, we talked about the details such as the history, design, classification and usage areas of the "Unmanned Underwater Vehicle" projects. In addition, we explained the advantages and disadvantages of the vehicle design details and the issues such as case studies, sample brands, and for which tasks they were manufactured. Methods to be used, mission depth, function, range, other related components, mission duration, etc. various factors affect the design of the vehicle. Software and control systems, especially in military areas, are the most value-added and most valuable parts of the vehicle. The use of unmanned underwater vehicles in sports, scientific, military and many fields reveals an important potential. Studies and applications need to be increased rapidly. As UUV technologies develop and investments made in this field increase, competition will increase. In this way, more various vehicles will be produced and their use will increase. It is our hope that investments in this field will increase in our country and that the number of companies working on these technologies will increase. In this way, the scientific and technological accumulation of our country will increase and our country will gain strength.

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