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Prof. Dr. Babek Erdebilli , Department of Industrial Engineering, Ankara Yildirim Beyazit University, Ankara, Turkey

babek.erdebilli2015@gmail.com or berdebilli@aybu.edu.tr

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Prof. Dr. Babek Erdebilli, Department of Industrial Engineering, Ankara Yildirim Beyazit University, Ankara, Turkey

babek.erdebilli2015@gmail.com or berdebilli@aybu.edu.tr

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Prof. Dr. Babek Erdebilli , Department of Industrial Engineering, Ankara Yildirim Beyazit University, Ankara, Turkey

babek.erdebilli2015@gmail.com or berdebilli@aybu.edu.tr

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**Dynamic Energy and Cost-Efficient Multi-UAV Routing Problem Using Enhanced Genetic Algorithm**

Dr. Alparslan GÜZEY1\*, Prof. Dr. Mehmet Hakan SATMAN2

1Department of Econometrics, Istanbul University, Istanbul, Türkiye

ORCID No: https://orcid.org/0000-0002-9043-304X

2Department of Econometrics, Istanbul University, Istanbul, Türkiye

ORCID No: https://orcid.org/0000-0002-9402-1982

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| **Keyword** | **Abstract** |
| *Capacitated Multi-UAV Routing, Energy Efficiency, Enhanced Genetic Algorithm, UAV Speed Dynamism* | *In this study we propose a novel method for capacitating multi-UAV multi- visit routing problem. Our main focus is on achieving energy and cost effectiveness by using an enhanced genetic algorithm. We delve into the adjustment of UAV speeds based on payloads and study how it impacts energy consumption and operational expenses. Our comprehensive model takes into account the relationships between payload mass, UAV velocity and power usage providing a roadmap for modern UAV delivery networks. Through testing we have demonstrated that our approach can handle the challenges posed by real world delivery scenarios showcasing its adaptability in managing various payload sizes and navigating complex routes. Our research not only confirms that our algorithm is flexible and capable of optimizing UAV delivery operations but also fills a research gap by incorporating speed variability and payload differences in the optimization process. The findings show that UAV-1 achieved optimal delivery efficiency with an initial high speed of 35.555 m/s and strategic speed adjustments based on payload weight, leading to significant energy savings. These enhancements underscore the real-world usefulness and reliability of our suggested technique. Our method provides a scalable solution for enhancing UAV operations, making it well suited for a range of uses.* |
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1. **INTRODUCTION**

The logistics and delivery industry has a transformation with the advent of UAV technology. UAVs provide alternative to ground transportation methods by navigating through terrains without being limited by road infrastructure. This presents an opportunity to expedite deliveries to improve efficiency and reduce impact. However, there are challenges associated with using UAVs for delivery purposes. These challenges include optimizing payload capacities for energy efficiency addressing safety

[[1]](#footnote-1)

concerns and developing routing algorithms that can adapt to real time variables. To fully harness the potential of UAV based delivery systems conducting research is crucial. The growing interest in drones for logistics and delivery systems from the demand for more effective delivery options in urban areas where traffic congestion and restricted access can impede traditional delivery methods. Drones offer a way to bypass these challenges by utilizing airspace resulting in more deliveries. Furthermore, the capability of drones to reach challenging locations makes them invaluable for deliveries like medical supplies in disaster affected regions. Despite these benefits there are operational obstacles that must be addressed to establish drone delivery systems on a broad scale. Key challenges include ensuring the safety and dependability of drone operations in populated areas. Drones need to be equipped with navigation and collision avoidance systems to prevent accidents. Additionally, the regulatory landscape for drones is still evolving, with countries imposing rules on drone flights, particularly those conducted beyond visual line of sight (BVLOS). These regulations must be carefully taken into account when developing drone delivery systems. Another significant challenge is the battery life of drones, which limits their range and payload capacity. Research into energy management and battery technologies is crucial to expand operational reach and improve overall efficiency of drone delivery systems.

In our study we have made contributions to addressing these challenges outlined in existing literature. Here are the key aspects:

* We have developed an algorithm specifically designed to solve the capacitated multi-UAV multi visit routing problem. This approach allows us to optimize both routing efficiency and energy consumption in UAV delivery systems.
* Unlike current studies, we have thoroughly investigated how adjusting UAV speeds based on varying payloads can affect energy efficiency and operational costs. This factor, which has been largely overlooked in the literature far is carefully considered in our research as we are taking an approach, towards modeling delivery systems.
* We have tackled the problem of linear energy consumption associated with the dynamics of UAV payload and speed by introducing a model that accurately represents their complex relationship. This model does not enhance the realism of our simulations, Also enables us to optimize UAV operations in various conditions more effectively.
* To validate our proposed algorithm, we conducted computational experiments that closely resemble real world delivery challenges. These experiments showcase algorithms adaptability, payloads, route complexities and operational requirements showing its potential to enhance the efficiency of UAV based delivery services.

Through these contributions our research fills gaps in existing literature by creating a framework for optimizing UAV delivery systems. This framework ensures adjustment to needs while simultaneously minimizing energy usage and costs.

The sections of the paper are structured as follows; In Section II a thorough review of existing literature is presented to establish an understanding of the status of UAV assisted delivery systems. Section III introduces the problem formulation, including decision variables, constraints and our chosen approach. It also provides an explanation of the function and calculations, for various aspects such as segment capacity and energy constraints. In Section IV we delve into the methodology by elaborating on the steps involved in the Genetic

Algorithm (GA) process. We also discussed how we integrated K Means Clustering and the 2 Opt Algorithm within the GA framework to adapt it specifically for UAV delivery purposes. Moving on to Section V we present results that encompass simulation setup details along with an analysis and discussion of these results. Lastly in Section VI we conclude this paper by summarizing our contributions highlighting real world applications and benefits suggesting areas for research and proposing improvements.

1. **LITERATURE REVIEW**

Dorling and colleagues (Dorling et al., 2017) used the realm of UAV delivery by focusing on vehicle routing problems. They provide insights into the derivation of an energy consumption model for multirotor UAVs highlighting the correlation between energy usage, payload capacity and battery weight. (Otto et al., 2018) conduct a literature survey on optimization approaches for aerial vehicles (UAVs) in civil applications. Their research offers an overview of optimization strategies specifically tailored to UAVs and their applications in remote sensing.

There have been studies focusing on UAV routing taking into consideration factors like linear energy consumption (Bruni et al., 2023), wind effects for energy saving in a truck UAV delivery system (Sorbelli et al., 2023) and power consumption rate and wind effects in the vehicle routing problem involving UAVs (Kim & Kim, 2022). These studies have made contributions to developing operational models and mathematical optimization techniques, for achieving energy efficient UAV routing. The field of UAV routing has seen advancements in algorithmic approaches. For instance (Zudio et al., 2021) developed a key genetic algorithm to tackle the hybrid vehicle UAV routing problem, for pickup and delivery. (G. Wu et al., 2022) proposed a coordinated vehicle UAV arc routing approach that leverages improved neighborhood search techniques. These studies have primarily focused on devising optimization techniques and heuristic algorithms to address complex UAV routing problems.

(Khan et al., 2022) presented a Dynamic UAV approach tailored for disaster scenarios offering energy efficiency through event/weather prediction and efficient path planning strategies. (Melo et al., 2021) tackled the challenge of achieving optimality in UAV path planning by emphasizing factors such as time, cost and energy efficiency. (J. Li et al., 2022) highlighted the nature of dynamic path planning and its potential to enhance UAV flight efficiency.

Recent research has focused on optimizing drone scheduling through multi-objective mixed integer programming models. A study by (Nikolić et al., 2023) proposed a mixed integer linear programming formulation aimed at minimizing total delays in servicing tasks and the total flying time of all drones, taking into account task duration and significance. The study's results, obtained using CPLEX to solve the generated MILPs, indicate that task assignments on a fleet of drones depend significantly on drone speed and the number of drones analyzed.

(Meng et al., 2023) propose a novel two-stage heuristic algorithm in which a maximum payload method is developed to construct the initial solutions, followed by an improved simulated annealing algorithm with problem-specific neighborhood operators and tailored acceleration strategies.

According to (C. Huang et al., 2018) the importance of dynamic path planning, for UAVs, in accomplishing missions was highlighted. Similarly, (Pachayappan & Sudhakar, 2021) proposed a solution to address UAV routing challenges by implementing docking stations for pickup and delivery services. Specifically, their approach aims to optimize both energy efficiency and cost effectiveness. Consequently, these studies collectively provide insights into the development of approaches, optimization algorithms and energy aware routing strategies for UAVs in dynamic path planning scenarios. The capacitated UAV routing problem (CDRP) entails assigning UAVs with carrying capacity to cater to a group of customers while minimizing operational costs. For instance, (Q. Wu et al., 2018) proposed a UAV wireless communication system, where multiple UAVs are utilized to serve users on the ground within a specified 2D region. Their study underscores the collaborative nature of systems.

(Sacramento et al., 2019) proposed a neighborhood search metaheuristic specifically designed for solving the vehicle routing problem with UAVs. Notably, they emphasized the significance of route planning and resource allocation in optimizing delivery operations.

Efficiently managing energy and costs while routing is crucial, for optimizing the efficiency of multi-UAV systems. According to (Dorling et al., 2017), developing vehicle routing problems (VRPs) for UAV delivery scenarios is significant, therefore highlighting the importance of path planning for UAV operations.

In the context of UAV systems, the multi visit routing problem plays a critical role especially when considering the vehicle routing problem with UAVs (Nuryanti, 2023). Nuryanti also emphasizes the importance of optimizing multi visit path planning by using the Tabu search algorithm and Analytical Hierarchy Process. These approaches address challenges through mapping and mathematical optimization techniques. Furthermore (Poikonen & Campbell, 2020) highlighted those new contributions, in UAV research should focus on models of UAV types and new UAV applications.

(Claro et al., 2023) emphasized the significance of factoring in characteristics of UAVs such as weight when planning energy paths highlighting the necessity for dynamic adjustments to accommodate variations in payload weight.

In a publication by (Y. Huang et al., 2022), it was highlighted that existing coverage path planning algorithms often make assumptions about constant UAV speed. The authors stressed the significance of incorporating dynamic speed adjustments to account for factors such as turns, including deceleration, turning and acceleration. (Y. Li et al., 2022) proposed an extension to the Q learning mechanism to address the exploration exploitation dilemma by introducing an exploration factor. It is possible to extend this approach to facilitate dynamic path adjustments based on variations in payload.

1. **PROBLEM FORMULATION**

In this section, we explained our model that will optimize the process from the central warehouse to the delivery points by UAVs to predetermined delivery points, under capacity, energy and time constraints.

The main purpose of our study is to optimize the total flight time, energy consumption and total subtour distance of each segment separately while delivering UAVs to multiple points. In this context, it is aimed to make the overall delivery task operationally sustainable by minimizing resources such as energy efficiency and total cost minimization.

**Table 1.** Notations

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* 1. **Decision Variables**

The decision variables we used in the formulation of our model are explained below:

* Route Assignment R{d,p}: It is a binary variable indicating whether the delivery point p is on the UAV d subtour route R{d,p} = 1 , it will take the value 1 if the UAV d is assigned to the delivery point p, and 0 otherwise R{d,p} = 0.
* Load Distribution L{d,p}: It is a type of continuous variable that represents the weight of the payload carried by the UAV d to the delivery point p.
* Energy Consumption s}: It is a continuous type of variable that calculates energy

consumed by the UAV d during the flight segment s. It takes into account the total payload, speed and total segment flight distance of the UAV in that flight segment s.

* Flight Speed V{d,s}: It is a continuous type of variable that represents the flight speed of the UAV d in the flight segment s. It aims at energy efficiency by dynamically determining the speed of the UAV according to its weight at the beginning of the flight segments.

The decision variables described above are elements of the optimization process that forms the basis of our research. Through these variables, the assignment of delivery points to UAVs, payload distribution according to UAV capacity, and dynamic adjustment of UAV speeds within the subtour allow energy efficiency to be achieved. By ensuring optimal adjustment of these variables, operationally efficient and effective resource use of the UAV overall mission will be ensured. In this way, it will offer sustainable and applicable solutions in all application areas where last-mile delivery is made.

This research sets itself apart from studies by incorporating dynamic speed adjustments based on payload weight, which is a relatively unexplored aspect within UAV routing problems. While past research has mainly focused on fixed speeds and linear models for energy consumption our method presents a comprehensive model that considers the complex relationship between UAV speed, payload mass and energy usage. This improvement does not enhance efficiency but also ensures that the proposed solution can adapt to real world delivery scenarios where payloads and routes may vary significantly. Through experiments that replicate real world conditions we validate our model and showcase its practical applicability and reliability, in optimizing UAV operations for a range of logistical tasks.

* 1. **Methodological Approach**

To achieve these goals, we have implemented an Enhanced Genetic Algorithm (EGA) combined with K Means clustering for grouping of delivery points providing a dual optimization strategy.

Initial Clustering: We utilize K Means clustering to group delivery points based on their proximity. This step forms the foundation for assigning routes to UAVs aiming to minimize the initial distances covered. Genetic Algorithm Optimization: The EGA explores potential routing solutions, where each solution represents a set of delivery routes covering all designated points. The effectiveness or "fitness" of each solution is evaluated using our function prioritizing solutions that minimize overall delivery costs. The solutions in the Genetic Algorithm (GA) go through a series of refining steps, including selection, crossover and mutation processes. These steps help the GA converge towards a set of delivery routes that're either optimal or very close to optimal. Moreover, we also take into account adjustments in speed and payload to enhance energy efficiency. We consider the dynamic relationship between UAV speed, payload weight and energy consumption to ensure optimization.

This framework represents the challenges faced by real world UAV delivery systems taking into account practical limitations such as energy capacity and payload restrictions. Our customized approach aims to provide a efficient and scalable solution for autonomous UAV-based delivery systems. We emphasize the importance of adaptability to operational scenarios and environmental conditions.

* 1. **Objective Function**

The goal of our UAV delivery system is to minimize the total flight duration for all UAVs involved in the mission. Considering the variability in UAV speeds and the significance of energy consumption we formulate the function as follows.

Where:

* *Z* represents the total flight duration that we aim to minimize.
* *K* denotes the number of UAVs being used.
* *N* corresponds to the number of delivery points, includ- ing the depot.
* *tijk* indicates the time taken for UAV *k* to travel directly from point *i* to point *j*, considering variable speeds.
* *xijk* is a binary variable that equals 1 if UAV *k* travels directly from point *i* to point *j*, and 0 otherwise.
  1. **Constraints**

Our model addresses several key operational constraints to ensure realistic and viable delivery route optimization:

Payload Capacity: Each UAV is designed with a maximum payload capacity to ensure that it doesn't carry more than its safe and optimal load. This helps maintain safety standards and compliance with regulations.

Energy Consumption: It is crucial to optimize the battery life of UAVs. Our model takes into account factors such as payload, flight speed and travel distance to minimize energy consumption. This does not extend the operational range of the UAVs but also enhances overall efficiency.

Delivery Point Servicing: Ensuring that each package reaches its designated delivery point is of importance. Our model guarantees coverage of all delivery points leaving no destination overlooked or unattended.

* + 1. ***Capacity Constraint***

The capacity constraint plays a role in the UAV delivery system ensuring that each UAV is not overloaded beyond its maximum payload capacity. This constraint is vital for the feasibility and safety of the UAV routes.

Mathematically we can express the capacity constraint for each UAV as follows;

Where,

* + - * , calculates the weight of all packages in the route of UAV d.
      * max \_𝑝𝑎𝑦𝑙𝑜𝑎𝑑, represents the weight that a UAV can carry.
      * ∀𝑑 ∈ 𝐷 , indicates that this constraint applies to every UAV in the set *D*.
    1. ***Energy Constraint***

When it comes to our UAV delivery system, one of the factors we consider is how to effectively manage our energy resources. We have implemented a mechanism known as the energy constraint to ensure that our UAVs can complete their delivery tasks successfully without draining their batteries.

The energy constraint plays a role in determining which delivery tasks are assigned to each UAV and helps with planning the route. We only assign a task to a UAV if it meets the energy constraint criteria. If a specific subtask requires than 80% of the UAV’s battery capacity, we consider the UAV unsuitable for that particular task. In cases our system. Selects another UAV with enough battery capacity or adjusts the route to reduce energy demands. This approach guarantees that our UAVs won’t run out of power midway through their routes ensuring both efficiency and safety.

The following notations used for formulation:

* *E*segment (*m, h, d*): Represents the energy consumption of a segment, which depends on the UAV’s mass *m*, height *h*, and distance *d.*
* *E*total: Denotes the energy consumption for subtour of the UAV’s route.
* *B*current: Refers to the battery capacity of the UAV.
* route: represents the collection of segments, in the UAV’s path.

To calculate the energy for a part of the route we add up all individual segment energies:

The energy constraint is then expressed as follows:

* + 1. ***Routing Constraints***

The routing constraints guarantee that every delivery point is visited once by a UAV and that each UAV’s route begins and ends at the depot.

Constraint for Visiting Delivery Points This constraint ensures that each delivery point is visited by one UAV. It can be expressed as follows;

(5)

According to this equation for every delivery point *j* there should be one route from a different point

*i* taken by any UAV *k*.

Constraint for Depot Start- End This constraint ensures that each UAV’s route starts and ends at the depot. It can be formulated as two equations;

These equations ensure that for each UAV *k* there is one route starting from the depot (represented as point ’0’) to a delivery point *j* and one route returning from a delivery point *i* back, to the depot.

* 1. **Time Calculation for Each Segment**

We calculate each segments time *tijk* based on factors such as distance, between points and variable speed of the UAV. Calculation is presented in the way;

(8)

Where:

* *dij* denotes the Euclidean distance between points *i* and *j*.
* *vijk* represent the speed of UAV *k* when traveling from point *i* to point *j*.
  + 1. ***Calculation of Distance***

The distance denoted as *dij* between two points (*x*1*, y*1) and (*x*2*, y*2) can be determined by using the following formula:

(9)

where (*x*1*, y*1) and (*x*2*, y*2) are the coordinates of points *i* and *j*, respectively.

* + 1. ***Calculation of Speed***

The optimal speed *vijk* of UAV *k* for the segment from point *i* to point *j* is calculated considering various factors such as the total mass of the UAV including its payload, aerodynamic characteristics, and environmental conditions. Formula used is:

where *V*opt represents a function that calculates the optimal speed for minimizing energy consumption while maintaining aerodynamic efficiency. In this context:

* *mk* is the base weight of the UAV.
* payload (*i, j*) is the weight of the payload being carried from point *i* to point *j*.
* *A* is the cross-sectional area exposed to airflow.
* *Cd* is the drag coefficient, which quantifies the UAV’s resistance to motion through air.
* *ρ* is the air density, which affects the aerodynamic forces experienced by the UAV.

The function *V*opt is derived from standard principles of aerodynamics, balancing the need for speed with energy efficiency to optimize the UAV’s performance across varying payloads and environmental conditions. This relationship is fundamental in UAV operations, particularly when efficient route completion is critical under dynamic conditions.

* 1. **Calculating Optimal Speed**

Finding the speed for a UAV is essential to ensure flight, where energy consumption and aerodynamic efficiency are balanced. In this section we will outline the approach used to determine the speed of a UAV taking into account factors such as its weight, aerodynamic properties and environmental conditions.

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**Figure 1**. Optimal speed algorithm

Weight factor: To start off we calculate the weight factor *Wf* by considering the base weight of the UAV *Wb*. Its maximum payload *Mp*. This weight factor helps adjust the speed range based on the weight of the UAV.

Determining Minimum and Maximum Speeds: we determine both the*Vmin* and *Vmax* speeds that our UAV can achieve. We also take into account base minimum *Vbmin*. Maximum *Vbmax* speeds in this calculation.

(12)

(13)

Power Required at a Given Speed: The power required at a given speed, *Pr* (*s*), is crucial for understanding the energy demands of UAV flight operations. This power is the sum of the forces needed to overcome aerodynamic drag and gravitational forces, particularly when changing altitude. The required power at speed *s* is calculated as follows:

(14)

(15)

where:

* *Df* (*s*) represents the drag force acting on the UAV at speed *s*.
* *m* is the total mass of the UAV, including its payload.
* *g* is the acceleration due to gravity, relevant for vertical movement components.
* *s* is the speed of the UAV.
* *ρ* is the air density.
* *Cd* is the drag coefficient.
* *A* is the effective cross-sectional area facing the airflow.

The first equation integrates the drag force, derived from the basic drag equation in fluid dynamics, with the gravitational force component when ascending or descending. This comprehensive approach to calculating power requirements ensures that the UAV’s battery and motor capabilities are adequately specified to handle various flight conditions efficiently.

* 1. **Calculating Energy Consumption for UAV Flight Segment**

In this section, we calculated the process of determining the energy needs for each segment of a UAVs flight. This calculation is essential for optimizing flight paths maximizing energy efficiency and extending the range of UAVs. The section begins by outlining an approach that outlines the inputs and outputs for calculating segment energy. This algorithm serves as a foundation for calculations and theoretical explanations of the UAVs flight dynamics.

The section breaks down the energy calculation into components each addressing a specific aspect of the UAVs flight. It starts by calculating takeoff time, which’s crucial in understanding the phase of the UAVs journey. Then it focuses on determining the acceleration required to reach the desired altitude, which significantly impacts energy consumption during ascent. Next it provides an analysis of takeoff dynamics covering both positive and negative acceleration phases to ensure a transition from ground to hover. The section also delves into power requirements during takeoff, cruising and landing stages to give an encompassing view of energy dynamics throughout the flight. Ultimately these calculations culminate in determining segment energy expressed in Watt hours measure, for real world applications. The careful method of calculating energy segments highlights the significance of accuracy in planning UAV flights. Emphasizes the necessity for algorithms to improve operational efficiency.

A screenshot of a computer program

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**Figure 2.** UAV segment energy algorithm

* + 1. ***Take-off Dynamic***

To determine the time needed for takeoff denoted as *t*takeoff, we use the altitude change *h* and the optimal speed *v*opt, in the formula;

(16)

* + 1. ***Acceleration Calculation***

To understand how a UAV takes off it’s important to grasp the significance of the acceleration coefficient *ε* in achieving flight performance. The acceleration coefficient plays a role, in ensuring that the UAV maintains a speed during both takeoff and landing aligning with its constant speed during the cruising phase. This alignment is vital for maintaining efficiency and stability throughout the flight.

Determining *ε* involves calculating a speed denoted as *Vopt* , which is considered ideal for the UAVs operation. Since average speeds differ across flight segments (takeoff and landing versus cruising) separate calculations are made for each segment. This tailored approach allows for management of acceleration to efficiently achieve *Vopt* .

During takeoff acceleration is divided into negative phases; first accelerating to *g* + *ε* to gain altitude up to *h/*2 then decelerating to *g ε* to reach the desired altitude *h.* This segmentation optimizes the UAVs performance by calculating *ε* for each phase. By doing the UAV, we can maintain an average speed that facilitates seamless transitions between different flight modes from takeoff, to cruising and finally landing. The process of taking off and landing with a UAV involves two distinct acceleration phases to reach a specific altitude *h*.

Take-off Dynamics: During takeoff there are two phases of acceleration;

* Positive Acceleration Phase (Ground to *h/*2): The UAV accelerates by applying a force to *g*

+ *ε* from the ground to an altitude of *h/*2 . This phase ensures altitude gain.

* Negative Acceleration Phase (*h/*2 to *h*): From an altitude of *h/*2 to *h* the UAV decelerates by applying a force to *g ε*, in order to smoothly transition into a state at altitude *h*.

A diagram of a drone landing

Description automatically generated

**Figure 3.** UAV segment

flight Landing Dynamics: During landing there are two phase of acceleration;

* Deceleration Phase (*h* to *h/*2): To land the UAV gradually descends from an altitude of *h* by accelerating downwards with a force of *g* + *ε* until it reaches an altitude of *h/*2 effectively controlling its descent rate.
* Final Approach Phase (*h/*2 to Landing): From an altitude of *h/*2 to the landing point the UAV applies a force of *g ε* to slow down its descent and ensure a controlled and smooth landing.

To ensure an efficient and controlled climb, to a desired height *h* in a time period *t* we use a two-step acceleration strategy. This technique is based on the core principles of kinematics of how objects move with acceleration.

The fundamental equation in kinematics, for an object starting from rest and experiencing acceleration is as follows:

(17)

where:

* *s* denotes displacement,
* *u* initial velocity,
* *a* acceleration,
* *t* represents time.

To determine the required acceleration *ε* for the UAV to reach an altitude of *h* within a time frame *t* we utilize the position equation during the half of ascent. This two-phase acceleration strategy ensures an efficient climb to the desired altitude.

(18)

Solving for *ε*, we get:

(19)

This two-phase acceleration approach ensures a smooth and efficient ascent to the desired altitude.

* + 1. **Take-off, Cruise, and Landing Power Calculations**

Take-off: Building upon the research conducted by (Leishman, 2006) on rotor helicopters and further expanded upon (Dorling et al., 2017), we can calculate the power *P* necessary for a single rotor helicopter to maintain hover using the aerodynamic principles described.

(20)

The thrust *T* can be determined as follows:

(21)

with *W* represents the weight of the frame, *m* is the combined weight of the battery and payload , *g* denotes acceleration due, to gravity , *ρ* represents air density and *σ* refers to the area of the spinning blade disc.

To calculate the power required for takeoff (*P*takeoff) we need to generate lift to counteract the weight of the UAV and provide acceleration. This can be calculated using:

Lift Force: (22)

Power to Lift: (23)

Air Velocity by Rotors: (24)

where:

* *m* is the mass of the UAV,
* *g* is the acceleration due to gravity,
* *ε* refers to acceleration,
* *ρ* denotes air density,
* *A* represents total rotor area and
* *η* signifies efficiency of propulsion system.

By combining these calculations, we can accurately deter- mine the power required for takeoff while considering both aerodynamic principles that govern UAV flight.

Cruise: During the cruise phase of a UAVs flight the total power required is a combination of the power needed to maintain hover and the power needed to overcome drag.

The overall power required for cruising denoted as *P*cruise is the sum of the power to sustain lift and the power needed to parasitic drag when moving forward. According to (Thibbotuwawa et al., 2019), parasitic drag force *FP* can be modeled as follows:

(25)

*CD* represents the drag coefficient, *AD* is the reference area of the UAV, *ρ* stands for air density and *v* denotes the velocity of the UAV, to the air.

As a result, we can calculate the power required to overcome this drag *P*drag using;

(26)

Hover power refers to the energy required for maintaining a stationary position by generating lift equal to that of the UAVs weight. It can be approximated by:

(27)

Combine the power of hovering and dragging, get the power needed for cruising:

(28)

This approach offers an understanding of the power requirements during the cruise phase taking into consideration both lifting and aerodynamic resistance.

Landing: The power necessary for landing *P*landing is assumed to be equivalent to that required for takeoff.

𝑃𝑙𝑎𝑛𝑑𝑖𝑛g= 𝑃𝑡𝑎𝑘𝑒𝑜𝑓𝑓 (29)

* + 1. ***Total Energy for the Segment***

Calculating the energy required for a UAVs route involves adding up the energy used during takeoff, cruising, and landing. This calculation is crucial, for mission planning and resource allocation to ensure that UAVs can complete their tasks efficiently without running out of energy. *E*segment, is the sum of the energy during takeoff, cruise, and landing:

(30)

Calculating flight time and energy plays a role in analyzing our UAV operations. As you can see in Algorithm 3, It focuses on determining how time and energy a UAV needs to complete a specific route. This calculation is vital, for mission planning and resource management ensuring that UAVs can carry out their tasks efficiently without running out of energy.

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**Figure 4.** UAV flight time and energy algorithm

1. **METHODOLOGY**

In this section we have applied a framework that combines different techniques to investigate the relationship between payload capacity, flight speed and energy efficiency in UAV logistics. Our approach involves three methods; K Means clustering, an enhanced genetic algorithm and the 2 opt heuristic. To begin with we used K Means clustering to categorize delivery destinations into clusters. This allowed us to assign each cluster to UAVs ensuring a distribution of delivery tasks. Once the clusters were established our enhanced genetic algorithm took over. Its main objective was to determine the flight routes by considering factors such as distance between points, payload capacities of the UAVs and their associated energy requirements. To further optimize these routes, we employed the 2 opt heuristic. This technique carefully rearranged the stops within each route to minimize travel distance and consequently reduce energy consumption. By combining these strategies in a manner, we were able to thoroughly explore how UAV based delivery systems operate and gain valuable insights into improving UAV performance with regards to payload management speed regulation and energy utilization.

The population size, mutation rate and maximum generation were carefully selected based on testing to strike a balance between efficiency and the thoroughness of our genetic algorithms search process. For instance, the population size was chosen to maintain a range of solutions without converging quickly. The mutation rate was adjusted to introduce variation without disrupting progress towards convergence. Limiting the number of generations helped prevent computational time while still allowing the algorithm enough chances to discover nearly optimal solutions. These parameters play a role in how the algorithm performs by influencing how much exploration, versus exploitation occurs in searching for solutions ultimately impacting both speed of convergence and solution quality. Figure 5 shows UAV used in application (DroneEngr, 2024).

A red drone with blue stripes

Description automatically generated

**Figure 5.** UAV

Table 2 and table 3 shows package weights, coordinates, and the UAV specifications.

**Table 2.** Package weights and coordinates

|  |  |  |
| --- | --- | --- |
| **Point ID** | **Coordinates (x, y)** | **Package weight (kg)** |
| 0 | (342, 598) | 0 |
| 1 | (200, 900) | 5 |
| 2 | (120, 300) | 10 |
| 3 | (250, 990) | 15 |
| 4 | (300, 700) | 10 |
| 5 | (350, 500) | 20 |
| 6 | (400, 400) | 5 |
| 7 | (900, 150) | 10 |
| 8 | (600, 600) | 15 |
| 9 | (900, 100) | 5 |
| 10 | (550, 850) | 10 |

**Table 3.** UAV specifications

|  |  |
| --- | --- |
| **Specification** | **Value** |
| Number of UAVs (*D*) | 4 |
| Max payload per UAV (*Mp*) | 40 kg |
| UAV base weight (*Wb*) | 20 kg |
| Air density (*ρ*) | 1.225 kg/m3 |
| Drag coefficient (*Cd* ) | 1 |
| Wing area (*A*) | 2 m2 |
| Gravitational acceleration (*g*) | 9.81 m/s2 |
| Height for takeoff/landing (*h*) | 50 m |
| Base min/max speed (*Vbmin* , *Vbmax*) | Variable based on payload |

Genetic Algorithm (GA) that we used in our model is a method that draws inspiration from natural selection and genetics. It proves to be highly effective when it comes to solving optimization problems in the case of dynamic path planning, for multi-UAV systems used in last mile delivery. In our research we employ Genetic Algorithm (GA) to optimize the routes taken by UAVs (Unmanned Aerial Vehicles) with a focus on achieving energy and cost efficiency. This section provides an explanation of how we have adopted GA methodology to tackle the challenges faced by UAV-based delivery systems. The foundation of our GA methodology lies in Darwin’s theory of evolution, which highlights the importance of survival and evolution of the solutions. In our case each potential route configuration for UAVs is considered as a chromosome with individual segments representing genes that make up these routes. The effectiveness of each solution is evaluated based on its efficiency in terms of energy consumption, delivery time and adherence to payload constraints.

As you can see in Fig. 6. our approach using GA is characterized by its nature as it maintains and evolves a population of solutions over generations. This method ensures improvement in the search for the efficient routes for UAV deliveries.

* 1. **Steps In Genetic Algorithm Process**

The parameters for Population Size and Maximum Generations were determined through empirical testing, aimed at balancing the computational efficiency with the depth and diversity of the search process in our genetic algorithm.

The Population Size was established based on iterative trials to identify a size that allows sufficient diversity while avoiding both premature convergence and excessive computational load. This size ensures a robust search across the genetic landscape, enhancing the algorithm’s ability to find near- optimal solutions without getting trapped in local minimal. Maximum Generations were set by observing the point at which improvements in solution quality plateaued over successive runs, indicating convergence of the algorithm. This parameter helps in terminating the algorithm once additional iterations cease to provide significant value, thus optimizing computational resources and time. These parameters were adjusted through a series of preliminary simulations, testing various scenarios to strike an optimal balance that accommodates the complexities of multi- UAV routing problems while maintaining reasonable execution times.

Initial Population: The starting point of our algorithm (GA) is a set of UAV route configurations. Each configuration, called a chromosome consists of routes that represent sequences of delivery points. During initialization we aim to cover a range of solutions to thoroughly explore the search space.

Selection: This process is akin to selection based on evaluating fitness. The fittest solutions, which optimize delivery routes for time and energy efficiency while adhering to payload limits have a chance of being chosen for reproduction. To maintain a balance between exploiting the solutions and exploring possibilities we employ a roulette wheel mechanism to select solutions for the next generation.



**Figure 6.** Genetic algorithm process

Crossover: Crossover plays a role in producing solutions (offspring) by combining selected parent solutions. Our GA incorporates techniques like point or multi point crossover, where segments of parent routes are exchanged to create configurations.

Mutation: Mutation introduces changes to the offspring promoting diversity within the population and preventing convergence towards local optima. We carefully control the mutation rate to ensure it contributes to exploration without hindering progress, towards solutions.

* 1. **K-Means Clustering in Genetic Algorithm**

The K Means clustering technique plays a role in dividing delivery points into clusters each assigned to an Unmanned Aerial Vehicle (UAV). This process is vital for generating the population in Genetic Algorithms (GA).

The goal of the K-Means clustering algorithm is to partition *n* delivery points into *K* clusters ensuring that each point *pi* belongs to the cluster with the mean. This creates a partition *S* = *S*1*, S*2*, . . . , SK* , with the objective of minimizing the sum of squares within each cluster (WCSS):

(31)

where *µ* is the mean of points in 𝑆𝑖 .

Implementing into Genetic Algortihm

* The K Means technique is employed to assign delivery points to UAVs based on their proximity, which establishes the routes.
* This clustering approach forms the foundation of the population within Genetic Algorithms (GA) guaranteing a set of starting solutions.
  1. **2-Opt Algorithm in Genetic Algorithm**

The 2 Opt algorithm serves as a search method utilized to enhance the routes generated by Genetic Algorithms (GA). It consistently replaces two edges with two edges to decrease the route length.

* Lets consider a route denoted as R, which consists of points *R* = (*r*1*, r*2*, . . . , rn*).
* In the 2 Opt technique we removed two edges (*ri, ri*+1) and (*rj, rj*+1). Then reconnect the paths formed.
* The resulting new route is denoted as R’ which follows the order *R′* = (*r*1*, . . . , ri, rj, . . . , ri*+1*, rj*+1*, . . . , rn*).
* We keep this change only if it reduces the distance of the route. Implementing into Genetic Algorithm
* In a Genetic Algorithm (GA) after performing crossover and mutation steps on each offspring.
* We apply the 2 Opt technique to refine each route individually.
* This step focuses on optimizing the order in which delivery points are visited.
* It helps prevent getting trapped in solutions and enhances the overall fitness of the population.
  1. **Multi-UAV System Implementation**

Calculating Distances: To plan the route of each UAV effectively it is essential to determine the distances between delivery points. The distance for each segment of a route can be calculated using the formula:

(32)

This formula enables us to compute the straight-line distance between any two points *i* and *j*, where (*xi, yi*) and (*xj, yj*) represent their coordinates.

Optimal Speed and Energy Calculation: To maximize efficiency while minimizing energy consumption it is crucial to determine the speed for each segment of a UAVs route. The optimal speed considers factors, like the UAVs weight and aerodynamic properties. It can be calculated as follows;

(33)

Additionally, we need to consider the energy required for completing each segment of the route including takeoff, cruising and landing phases:

(34)

This energy calculation incorporates parameters and aerodynamic principles. The formulate (33) and

(34) contribute to a model that optimizes UAV flight paths by calculating the necessary energy.

1. **COMPUTATIONAL RESULTS**

Our research delves into the Capacitated UAV Routing Problem (CDRP) using a UAV approach with a focus, on optimizing energy and cost efficiency through a multi visit system. We devised our solution by employing a Genetic Algorithm, which incorporates the 2 Opt technique for route optimization well as the K means Clustering Method to efficiently allocate tasks among UAVs. These methodologies collectively address the nature of routing UAVs while considering capacity limitations, energy efficiency and operational expenses. To implement our solution, we utilized Python programming language in conjunction with the PyCharm Integrated Development Environment (IDE). Additionally, we leveraged the capabilities of Gourbi 11.0 to solve optimization problems. All computations were performed on a MacBook Pro computer equipped with an M3 chip and 8GB of RAM. This setup demonstrates that our approach is applicable on available computing platforms. The solvers parameters were kept at their default settings to ensure that our results can be reproduced reliably. Furthermore, to strike a balance between exploration and practical constraints we imposed a four-hour time limit on each experiment. By employing this framework, we were able to examine the effectiveness of our proposed methodologies in enhancing operational efficiency within UAV routing systems. Our findings underscore potential for advancements in UAV logistics.

* 1. **Simulation Setup**

Our simulation environment is carefully designed to add the complexities and limitations, in real world UAV delivery operations. The experimental parameters are as follows:

* Population Size: We have set it at 50 which determines the diversity of route solutions explored by our algorithm striking a balance between exploration and exploitation.
* Maximum Generations: Limited to 100 indicating the depth of search conducted for optimal route configurations.
* Mutation Rate: Kept at a fixed value of 0.1 this rate emphasizes the algorithms’ ability to introduce variability and avoid getting stuck in local optima.
* Tournament Size: Set at 5 representing the selection process for breeding within the algorithm framework.
* Battery Capacity: Our UAV fleet operates with a capacity of 300-watt hours determining their range and endurance.
* Number of UAVs: Our delivery fleet consists of four UAVs, which aligns with operational scalability and manageability considerations.
* UAV Specifications: Each UAV has a base weight of 20 kg and a maximum payload capacity of 40 kg. These parameters are crucial for understanding energy consumption and routing dynamics.
* Package Weights and Delivery Coordinates: To simulate delivery scenarios package weights vary from 5 to 20 kg. Additionally, delivery points are strategically dispersed to challenge the routing algorithm.

This configuration does not demonstrate the versatility of our model. Also investigates its boundaries and capacities when faced with diverse logistical limitations.

* 1. **Results**

In the operations of UAVs, adjustments in speed relative to changes in payload weight are strategically managed to optimize delivery efficiency. For UAV-1, the initial high speed of 35.555 m/s with a payload of 35 kg is employed to quickly cover the longer initial segment of the delivery route. As the UAV makes deliveries and the payload decreases, the speed is systematically reduced. This reduction in speed is not directly due to the decrease in payload but is a strategic decision to conserve energy and enhance flight safety as the UAV becomes lighter and more energy-efficient in its operations.

A table with numbers and a few words

Description automatically generated**Table 4.** UAV-1 subtour results

This adaptive speed management strategy ensures that UAVs operate effectively when carrying loads using an advanced control system to balance the goals of saving time and conserving energy. In the case of UAV-2 we noticed a decrease in the speed and acceleration coefficient (epsilon) as it moves along its delivery route starting at a speed of 17.777 m/s with a 15 kg load and gradually decreasing to 4.444 m/s as the load decreases to zero. This highlights how control mechanisms adjust speed based on payload weight during deliveries with energy consumption (210.667 Wh) heavily impacted by both the weight being carried and the distance traveled, emphasizing the need to optimize these factors for delivery efficiency.

**Table 5.** UAV-2 subtour results

A table with numbers and letters

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When we look at the results of UAV-3’s subtour, we can see that there is a balance between managing the payload and maximizing energy efficiency. At first the UAV carries a payload of 20 kg and reaches a speed of 22.222 m/s thanks to a higher acceleration coefficient (epsilon) of 0.617; as the payload decreases to 15 kg the speed decreases to 17.777 m/s. Eventually drops to 4.444 m/s with no payload showing significant energy savings. The total duration of this trip is 144.030 seconds, with an energy usage of 148.861 Wh highlighting how important it is to consider payload weight and flight dynamics when planning routes and adjusting speeds to improve the efficiency and performance of UAV delivery systems.

A white paper with black text and numbers

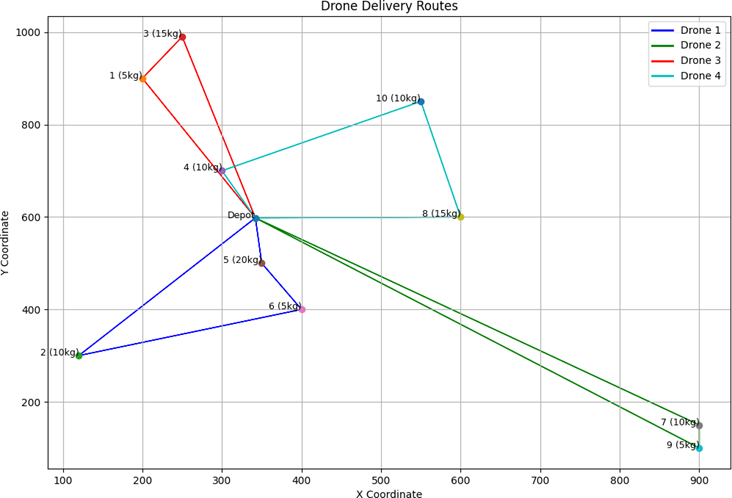
Description automatically generated**Table 6.** UAV-3 subtour results

The UAV-4 begin its route carrying a 35 kg payload reaching a speed of 35.555 m/s and an acceleration factor (epsilon) of 1.58. In the leg of the flight, it consumes 51.834 Wh of energy due to the load and high speed. As the mission progresses, the payload decreases to 25 kg. To 15 kg both the speed and epsilon decrease proportionally to 26.666 m/s and 17.777 m/s respectively allowing for more efficient energy usage. When flying without any payload the UAV maintains a speed of 4.444 m/s resulting in a reduction in energy consumption to only 27.857 Wh for this phase. It completes this part of the journey, in 121.115 seconds by adjusting its flight dynamics and energy consumption based on the changing payload weights.

**Table 7.** UAV-4 subtour results

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**Figure 7.** UAV mission delivery subtours

*Note: The total mission was completed in a time of 253.53 seconds, consuming a total energy of*

*746.64 Wh.*

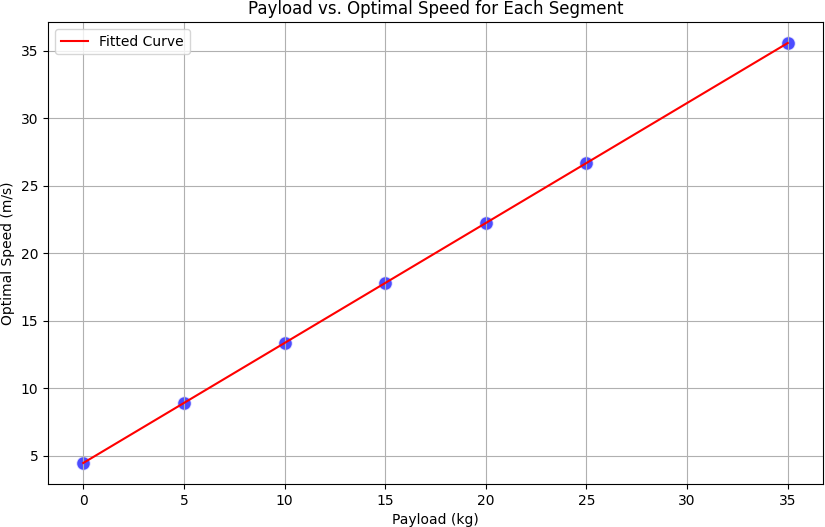
Fig. 7. provides an analysis of a UAV delivery mission, where UAVs are strategically deployed to balance payload distribution and route efficiency. The goal is to optimize delivery times and energy usage. UAV 1, which initially carried the load started off with speeds but gradually slowed down as deliveries were made. On the hand UAV 4 also started with a payload followed a more energy efficient route. UAV 2s longer flight time indicated that its route might have been longer or less efficient compared to others while UAV 3 maintained parameters throughout the mission. The overall mission was completed in 253.53 seconds consuming around 746.64 Wh of energy. This analysis highlighted the tradeoff between speed, payload capacity and energy consumption in UAV delivery systems. Identified potential areas for future optimization.

A graph of a speed of a drone

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**Figure 8.** UAV flight segment optimal speeds

Fig. 8 shows how UAVs change their speeds based on changes in payload weight when carrying out deliveries. At the beginning UAVs 1 and 4 begin with speeds of 35 m/s slowing down as their payloads get lighter, which improves efficiency towards the end of the mission. This chart emphasizes the tuning of UAV speeds to save energy and stresses the significance of adjusting speed for payload handling and route planning.



**Figure 9.** Payload optimal speeds

Figure 8 shows the correlation between UAV payload weights and their optimal speeds, offering analytical perspectives on operational efficiency in UAV delivery systems. The scatter plot, complemented by a curve, demonstrates that as UAVs carry heavier loads, they tend to operate at higher optimal speeds. This relationship is evident through aligned data points and a linear trend line highlighting the increase in speed with payload weight. These optimal speeds were determined using our proposed enhanced genetic algorithm, which dynamically adjusts UAV speeds based on payload weight to optimize energy consumption and operational efficiency. The findings suggest that heavier deliveries require faster travel to maintain optimal flight dynamics and manage energy effectively. The data used for this figure was generated through computational experiments conducted as part of this study, where various payload weights and UAV specifications were tested to observe their impact on optimal speeds.

A graph showing a graph of a graph

Description automatically generated with medium confidence

**Figure 10.** Payload acceleration coefficient

Fig. 10 shows the impact of payload weight, on UAV acceleration indicating that heavier loads demand power for acceleration. This is evident from the rise in the acceleration coefficient (Epsilon) as weight increases. The graph shows that UAVs maintain steady acceleration with payloads but adjustments in flight dynamics and power settings are required for heavier loads. The analysis emphasizes the link between payload weight and operational effectiveness emphasizing the importance of strategic UAV design and mission planning to enhance performance and energy efficiency.

A graph of energy consumption

Description automatically generated

**Figure 11.** Energy consumption per segment

In Fig. 11. we can get insights into the energy usage patterns of UAVs during delivery missions. It becomes evident that UAV 2 initially has energy demands, which could be attributed to a load or longer route. On the other hand, UAV 4 demonstrates energy use in the beginning indicating a lighter load or shorter initial segment. As the mission progresses all UAVs show a decrease in energy consumption across segments reflecting payload delivery and reduced energy requirements. Notably UAV 1 consistently consumes energy than the others suggesting its role in covering distances or carrying heavier payloads.

A graph of a graph with different colored lines

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**Figure 12.** Speed power consumption

Fig. 12 shows the relationship between UAV’s speed, its carried payload, and the consequent power requirements. The data clearly indicate a correlation where power consumption increases with speeds across different payload weights. This highlights the energy demands needed to counteract drag at velocities particularly when dealing with heavier payloads. Such insight is crucial for UAV design as it emphasizes the importance of strategic speed management to enhance energy efficiency and optimize performance.

A graph of a speed and speed

Description automatically generated

**Figure 13.** Speed endurance

In Fig. 13, it shows that when the speed of a UAV goes up its endurance goes down with payloads. This emphasizes the importance of flying UAVs, at a speed range to get the most out of their endurance. This evaluation is crucial for planning missions as it enables adjustments in UAV speeds based on payload weight ultimately improving efficiency in tasks, like delivery and surveillance.

A graph of different colored lines

Description automatically generated

**Figure 14.** Speed range

Fig. 14. shows that UAVs travel range diminishes as both payload and speed increase. To what was observed in terms of endurance. This indicates an inverse relationship between speed and range across all payloads. Heavier payloads have an impact on the range of UAVs. Much like their effect on endurance. By reducing flight time and distance capabilities when combined with increased speed. Consequently, this underscores the importance of managing speeds, for performance. The values presented in the figure (25 m to 250 m) are derived from specific test scenarios designed to highlight the impact of varying payloads and speeds on UAV range in a controlled environment. These values illustrate the trend rather than representing the maximum possible range of the UAVs. Consequently, this underscores the importance of managing speeds for optimal performance and efficiency in UAV operations.

1. **CONCLUSION AND FUTURE WORK**

In this study we worked on the performance of four UAVs by exploring aspects such, as speed enhancement, energy conservation, handling of payloads and acceleration features. UAVs 1. 4 demonstrate efficient speed control when carrying loads indicating thrust capabilities, especially UAV 4 which strikes a balance between payload capacity and speed implying a superior power to weight ratio. On the other hand, UAV 3 maintains speeds even with heavy payloads at either energy saving tactics or limitations in thrust compared to UAV 4. Meanwhile UAV 2 demonstrates energy efficiency by utilizing 65.963 Wh even during long flights showcasing effective cruising without any payload onboard. The declining energy usage as payloads are delivered for UAV 4 emphasizes advanced energy management aligned with task completion. This study highlights the importance of managing both the weight and energy consumption of UAVs to optimize delivery routes; it stresses

that controlling speed and distributing payloads are factors in improving operational efficiency and cost effectiveness in UAV logistics. Future research should concentrate on creating algorithms that can dynamically adapt routes and speeds based on changing circumstances and testing them in real world settings to enhance their efficacy while also refining energy consumption models to consider impacts for better deployment strategies of UAVs, in diverse delivery scenarios. Based on our findings, it is advisable for practitioners to implement systems that manage speed and payload dynamically to enhance energy efficiency and operational effectiveness. Policy makers should think about creating rules and regulations that promote the integration of drones into delivery networks emphasizing operation guidelines such as speed restrictions and payload capacities. Moreover, investing in research and development for battery technologies and energy efficient drone designs will play a role in expanding the reach and functionalities of drones. Collaboration between industry stakeholders and regulatory entities can help in establishing procedures for drone operations ensuring scalability and sustainability across logistical settings. These steps will harness the potential of drone technology in improving delivery services while reducing impact and operational expenses. The experiments conducted involved controlled settings, which may not encompass all factors encountered in real world scenarios like weather conditions, regulatory limitations and unforeseen obstacles. Additionally, the model assumes knowledge about payload weights and delivery locations information that may not always be readily available in situations. Future studies ought to address these uncertainties by exploring algorithms capable of adapting to real time data and dynamic changes in delivery environments. Despite these constraints the proposed model represents an advancement towards optimizing drone-based logistics operations while setting a foundation for research endeavors and practical applications.

**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest regarding the publication of this article.

**CONTRIBUTION OF AUTHORS**

Dr. Alparslan Güzey was responsible for the overall conceptualization, methodology, and preparation of the article. Prof. Dr. Mehmet Hakan Satman, as the Ph.D. supervisor, contributed by reviewing and providing critical feedback on the article.

**REFERENCES**

Bruni, M. E., Khodaparasti, S., & Perboli, G. (2023). Energy Efficient UAV-Based Last-Mile Delivery: A Tactical-Operational Model with Shared Depots and Non-Linear Energy Consumption. *IEEE Access*,

*11*. <https://doi.org/10.1109/access.2023.3247501>

Claro, R. M., Pereira, M. I., Neves, F. S., & Pinto, A. M. (2023). Energy Efficient Path Planning for 3D Aerial Inspections. *IEEE Access*, *11*, 32152–32166. IEEE Access. <https://doi.org/10.1109/ACCESS.2023.3262837>

Dorling, K., Heinrichs, J., Messier, G. G., & Magierowski, S. (2017). Vehicle Routing Problems for Drone Delivery. *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, *47*(1). <https://doi.org/10.1109/tsmc.2016.2582745>

DroneEngr. (2024). Heavy load drone with 40KGS payload 20 minutes endurance. *One-Stop Drone Parts Store. Save BIG*. http[s://www.droneassemble.com/product/heavy-load-drone-with-40kgs-payload-20-](https://www.droneassemble.com/product/heavy-load-drone-with-40kgs-payload-20-%20minutes-endurance/) minutes-endurance/

Huang, C., Lan, Y., Liu, Y., Zhou, W., Pei, H., Yang, L., Cheng, Y., Hao, Y., & Peng, Y. (2018). A New Dynamic Path Planning Approach for Unmanned Aerial Vehicles. *Complexity*, *2018*, e8420294. <https://doi.org/10.1155/2018/8420294>

Huang, Y., Xu, J., Shi, M., & Liu, L. (2022). Time-Efficient Coverage Path Planning for Energy-Constrained UAV. *Wireless Communications and Mobile Computing*, *2022*. <https://doi.org/10.1155/2022/5905809>

Khan, A., Zhang, J., Ahmad, S., Memon, S., Qureshi, H. A., & Ishfaq, M. (2022). Dynamic Positioning and Energy-Efficient Path Planning for Disaster Scenarios in 5G-Assisted Multi-UAV Environments. *Electronics*, *11*(14), Article 14. <https://doi.org/10.3390/electronics11142197>

Kim, S., & Kim, S. (2022). VRP of Drones Considering Power Consumption Rate and Wind Effects. *LOGI – Scientific Journal on Transport and Logistics*, *13*(1), 210–221. <https://doi.org/10.2478/logi-2022-0019>

Leishman, J. G. (2006). *Principles of helicopter aerodynamics* (2nd ed). Cambridge University Press. [https://doi.org/ 10.1017/S0001924000087352](https://doi.org/%2010.1017/S0001924000087352)

Li, J., Liu, H., Lai, K. K., & Ram, B. (2022). Vehicle and UAV Collaborative Delivery Path Optimization Model. *Mathematics*, *10*(20), 3744. <https://doi.org/10.3390/math10203744>

Li, Y., Liu, L., Wu, J., Wang, M., Zhou, H., & Huang, H. (2022). Optimal Searching Time Allocation for Information Collection Under Cooperative Path Planning of Multiple UAVs. *IEEE Transactions on Emerging Topics in Computational Intelligence*, *6*(5), 1030–1043. IEEE Transactions on Emerging Topics in Computational Intelligence. <https://doi.org/10.1109/TETCI.2021.3107488>

Melo, A. G., Pinto, M. F., Marcato, A. L. M., Honório, L. M., & Coelho, F. O. (2021). Dynamic Optimization and Heuristics Based Online Coverage Path Planning in 3D Environment for UAVs. *Sensors*, *21*(4), Article 4. <https://doi.org/10.3390/s21041108>

Meng, S., Guo, X., Li, D., & Liu, G. (2023). The multi-visit drone routing problem for pickup and delivery services. *Transportation Research Part E: Logistics and Transportation Review*, *169*, 102990. <https://doi.org/10.1016/j.tre.2022.102990>

Nikolić, M., Netjasov, F., Crnogorac, D., Milenković, M., & Glavić, D. (2023). Urban Air Mobility: Multi- objective Mixed Integer Programming Model for Solving the Drone Scheduling Problem. In O. Gervasi, B. Murgante, A. M. A. C. Rocha, C. Garau, F. Scorza, Y. Karaca, & C. M. Torre (Eds.), *Computational Science and Its Applications – ICCSA 2023 Workshops* (pp. 349–362). Springer Nature Switzerland. <https://doi.org/10.1007/978-3-031-37111-0_25>

Nuryanti, L. (2023). A Vehicle Routing Problem Optimization With Drone Using Tabu Search Algorithm and Analytical Hierarchy Process. *Majalah Ilmiah Pengkajian Industri*, *15*(1). <https://doi.org/10.29122/mipi.v15i1.4732>

Otto, A., Agatz, N., Campbell, J. F., Golden, B. L., & Pesch, E. (2018). Optimization approaches for civil applications of unmanned aerial vehicles (UAVs) or aerial drones: A survey. *Networks*, *72*(4). <https://doi.org/10.1002/net.21818>

Pachayappan, M., & Sudhakar, V. (2021). A Solution to Drone Routing Problems using Docking Stations for Pickup and Delivery Services. *Transportation Research Record*, *2675*(12), 1056–1074. <https://doi.org/10.1177/03611981211032219>

Poikonen, S., & Campbell, J. F. (2020). Future directions in drone routing research. *Networks*, *77*(1). <https://doi.org/10.1002/net.21982>

Sacramento, D., Pisinger, D., & Ropke, S. (2019). An adaptive large neighborhood search metaheuristic for the vehicle routing problem with drones. *Transportation Research Part C: Emerging Technologies*, *102*, 289–315. <https://doi.org/10.1016/j.trc.2019.02.018>

Sorbelli, F. B., Corò, F., Palazzetti, L., Pinotti, C. M., & Rigoni, G. (2023). How the Wind Can Be Leveraged for Saving Energy in a Truck-Drone Delivery System. *IEEE Transactions on Intelligent Transportation Systems*, *24*(4), 4038–4049. IEEE Transactions on Intelligent Transportation Systems. <https://doi.org/10.1109/TITS.2023.3234627>

Thibbotuwawa, A., Nielsen, P., Zbigniew, B., & Bocewicz, G. (2019). Energy Consumption in Unmanned Aerial Vehicles: A Review of Energy Consumption Models and Their Relation to the UAV Routing. In J. Świątek, L. Borzemski, & Z. Wilimowska (Eds.), *Information Systems Architecture and Technology: Proceedings of 39th International Conference on Information Systems Architecture and Technology – ISAT 2018* (pp. 173–184). Springer International Publishing. <https://doi.org/10.1007/978-3-319-99996-8_16>

Wu, G., Zhao, K., Cheng, J., & Ma, M. (2022). A Coordinated Vehicle–Drone Arc Routing Approach Based on Improved Adaptive Large Neighborhood Search. *Sensors*, *22*(10). <https://doi.org/10.3390/s22103702>

Wu, Q., Zeng, Y., & Zhang, R. (2018). Joint Trajectory and Communication Design for Multi-UAV Enabled Wireless Networks. *IEEE Transactions on Wireless Communications*, *17*(3), 2109–2121. IEEE Transactions on Wireless Communications. <https://doi.org/10.1109/TWC.2017.2789293>

Zudio, A., Coelho, I. M., & Ochi, L. S. (2021). Biased Random-key Genetic Algorithm for theHybrid Vehicle- drone Routing Problem for Pick-upand Delivery. *Anais Do 15. Congresso Brasileiro de Inteligência Computacional*, 1–6. <https://doi.org/10.21528/CBIC2021-107>

**Sürdürülebilir Mahalle İçin Yeşil Alan Ve Kamu Alanı Yer Seçimi: Keçiören Örneği**

Hüseyin KARATEKE 1[[2]](#footnote-2)

1Efe Eğitim Danışmanlık, Ankara

ORCID No: https://orcid.org/0000-0001-5441-2949

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| **Anahtar Kelimeler** | **Öz** |
| *Sürdürülebilir mahalle, Tesis yeri seçimi, Küme kapsama problemi, Maksimum kapsama problemi, Matematiksel model, Doğrusal programlama* | *Kentlerin genel karakteri bina ve yapı alanları, ulaşım alanları, açık ve yeşil alanlar arasındaki ilişkiye göre şekillenir. Kentler, hızlı nüfus artışı ve sanayi faaliyetleri nedeniyle ilişki dengesini kaybetmiş, sağlıksız, düzensiz ve kimliksiz hale gelmiş ve kentler sürdürülebilir olma özelliğini kaybetmiştir. Bina ve yapı alanlarının konumu ve yoğunluğu kentsel yaşamı dengelemek ve kentlerin yaşam kalitesi için açık yeşil alanlar büyük öneme sahiptir. Dengeli kentlerin oluşturulması için açık yeşil alanlara büyük önem veren gelişmiş ülkeler, insanların ihtiyaçlarını karşılamak için sürdürülebilir kent mekanı planlama ve tasarımına öncelik vermektedir. Kentlerde sürdürülebilir yaşamın sağlanması için sürdürülebilir mahallelerin planlamaya dâhil edilmesi önem arz etmektedir. Bu çalışmada Ankara ilinde kentsel dönüşüme girmiş ve nazım imar planı olan mahallerin yeşil alan, kamu alanı ve okul binası yer seçimi problemi çözülmüştür. Çalışmadaki ele alınan gerçek hayat uygulamasında minimum sayıda yeni tesisin atanması yapılmıştır. Fakat tüm talep düğümlerinin kapsanması gerekmemekte, belirli oranda talep düğümünün kapsanması yeterli görülmektedir. Bu sebeple bu çalışmada literatürde bilinen küme kapsama problemi ve maksimum kapsama problemi birleştirilerek yeni bir model geliştirmiştir. Model, doğrusal olmayan yapısı sebebiyle doğrusallaştırılmıştır. Modelin çözüm performansını değerlendirebilmek için, üç farklı gerçek hayat problemi GAMS programı yardımıyla geliştirilen modelle çözülmüş ve sonuçlar verilmiştir. Sonuçlar; beş parsele açık ve yeşil alan, dokuz sivil veya kamu alanı ataması yapılmıştır.* |

**Green Space And Public Space Location Selection For A Sustainable Neighborhood: Keçiören Example**

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| --- | --- | --- | --- | --- |
| **Keywords** | | **Abstract** | | |
| *Sustainable neighborhood, Facility location selection, Set covering problem, Maximum coverage problem, Mathematical model, Linear programming* | | *The general character of cities is shaped by the relationship between building and structure areas, transportation areas, open and green areas. Due to rapid population growth and industrial activities, cities have lost their balance of relationships, have become unhealthy, irregular and unidentified and cities have lost their sustainability. Open green spaces are of great importance for balancing the location and density of buildings and structure areas, urban life and the quality of life of cities. Developed countries, which attach great importance to open green spaces for the creation of balanced cities, prioritize sustainable urban space planning and design to meet the needs of people. In order to ensure sustainable life in cities, it is important to include sustainable neighborhoods in planning. In this study, the problem of green area, public area and school building location selection in neighborhoods that have undergone urban transformation and have a master development plan in Ankara is solved. In the real-life application discussed in the study, a minimum number of new facilities were assigned. However, it is not necessary to cover all demand nodes; covering a certain percentage of demand nodes is sufficient. For this reason, in this study, a new model is developed by combining the set covering problem and the maximum coverage problem known in the literature. The model is linearized due to its non-linear structure. In order to evaluate the solution performance of the model, three different real-life problems were solved with the model developed by using GAMS program and the results were given. Results; five parcels were assigned as open and green areas, and nine parcel were assigned as civil or public areas.* | | |
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**1. GİRİŞ**

Çevre, nüfus artışı ve insan faaliyetlerinden büyük ölçüde etkilenerek arazi değişiminde gözle görülür değişikliklere neden olmuştur. Bu değişikliklerin çevre üzerinde önemli etkileri bulunmaktadır. Nüfusun artmasıyla birlikte konut, ulaşım ve çevresel müdahaleler gibi çeşitli insan faaliyetlerinin hem dünya yüzeyi hem de kentsel alanlar üzerinde geri dönüşü olmayan sonuçları olmuştur. Bu nedenle, insan faaliyetlerinin çevre ve kentsel alanlar üzerindeki olumsuz etkilerini azaltmak için sürdürülebilir uygulamaların benimsenmesi büyük önem taşımaktadır (Coppin, Jonckheere, Nackaerts ve Muys, 2004).

Kentsel alanlardaki uygulamalarda ele alınan kriterlerden olan sürdürülebilirlik, kentlerin sürdürülebilir yönetiminden daha fazlasını kapsamaktadır. Köyler, kasabalar, şehirler ve metropoller de dâhil olmak üzere tüm insan yerleşimlerinin çeşitli boyutlarını kapsamaktadır. Bu boyutlar arasında barınma, sağlık, yönetişim, iş ve istihdam, refah, güvenlik, temizlik, eşitlik, eğitim, ulaşım, katılım, iş birliği, mimari, sanayi gibi hususlar yer almaktadır (Ng, Cook, ve Chui, 2001). Dünya Çevre ve Planlama Komisyonu tarafından 1987 yılında yayınlanan Brundtland Raporu, sürdürülebilir kentleri, gelecek nesillerin kendi ihtiyaçlarını karşılama kabiliyetinden ödün vermeden bugünün ihtiyaçlarını karşılayan kentler olarak tanımlamaktadır (Brundtland Report, 1987). Sürdürülebilirliği kentsel alanlara dâhil etmenin temel amacı, kaynakların adil ve çevreye duyarlı bir şekilde yönetilmesini ve planlanmasını hayata geçirerek gelecek nesillerin yaşam hakkını korumaktır. Bu yaklaşım, insan ve çevre sistemlerinin yanı sıra ekosistem hizmetlerinin kent sakinlerinin refah artışı üzerinde etki etmesini sağlamaktır (Meadows, Meadows Randers ve Behrens, 1972). Sonuç olarak, sürdürülebilirlik ilkeleri mahalleler ve binalar da dâhil olmak üzere çeşitli düzeylerde hayata geçirilmesiyle sürdürülebilir şehirler, eko şehirler, yeşil şehirler, sürdürülebilir kentsel kalkınma ve sürdürülebilirlik hedefleri gibi kavramlar ortaya çıkmış ve uygulanmaya başlanmıştır (Jickling, 1994). Kentsel alanları olumsuz etkilenmiş kentlerden sürdürülebilir kentlere dönüşüm gerçekleştirilmesi için kentlerde hayata geçirilen kentsel dönüşüm projeleri fırsat olarak karşımıza çıkmaktadır. Kentsel dönüşüm projeleri, sürdürülebilirlik ilkesini uyguladıkları takdirde sürdürülebilir kentsel kalkınmayı başarıyla gerçekleştirebilir. Bu projeler, sosyal, ekonomik veya fiziksel gerileme yaşamış bir kentin ekonomik büyümesini sürdürürken aynı zamanda düşük gelirli bireylerin yaşam koşullarını iyileştirmeyi amaçlamaktadır (Choguill, 2008). Sürdürülebilir kentsel dönüşüm, kentleri uzun vadede stratejik olarak planlamak için sivil toplum kuruluşları, özel sektör, yerel ve merkezi hükümetlerin ortak çabasını içermektedir. Amaç, kentsel gelişimin olumsuz etkilerini azaltmak, ekonomik rekabet gücünü artırmak, kentlerin genel fiziksel ve çevresel kalitesini artırmaktır (Mc Cormick, 2013).

1933’teki Atina Bildirgesi, işlevsel kentlerin önemini ve binaların bir araya gelerek uyumlu mahalleler oluşturması gerektiğini vurgulayarak mahalle birimi kavramını uluslararası alanda ön plana çıkarmıştır. Plancılar ve kentsel karar vericiler mahallelerin önemini uzun zamandır kabul etmektedir (Rohe, 2009). Yirminci yüzyıl boyunca daha cazibeli ve yaşanabilir mahalleler meydana getirmek için çok sayıda teori ve model geliştirilmiştir. Yaşanabilir mahalleler, kaliteli bir yaşam biçimini destekleyen hem kültürel hem de mimari yönleri kapsayan sürdürülebilirlik ilkelerine dayanmaktadır. Sürdürülebilir kalkınmanın ortaya çıkışı ve yerel düzeye yaptığı vurgu, mahalle planlamasına olan ilgiyi yeniden canlandırmış ve yenilikçi yaklaşımların geliştirilmesine yol açmıştır (Tang, 2002). Sürdürülebilir ve yaşanabilir mahalleler oluşturmak yaşam kalitesini korumak için önem arz etmektedir. Planlaması iyi yapılmış bir mahallede toplumun sosyal etkileşim potansiyeli artmaktadır. Çeşitli planlama stratejileri, yaya dostu sokakların ve karma kullanım alanlarını içeren kompakt kentsel formların geliştirilmesini teşvik ederek daha güçlü komşuluk ilişkilerini ve sosyal uyumu teşvik etmektedir (Roberts, 2008).

Mahalle düzeyinde ekolojik sürdürülebilirliği hayata geçirmek için çok sayıda standart geliştirilmiş ve bu standartları birleştiren sertifikasyon sistemlerinin uygulamaya konulması konusu önem kazanmıştır. Sertifikasyon prosedürleri, değerlendirmenin odağına göre üç gruba ayrılmaktadır. Bunlar; binalar, mahalleler ve tüm kent şeklinde sıralanabilir. Mahallelerin sürdürülebilirlik ölçütleri çerçevesinde değerlendirilmesi 2006 yılında ilk defa CASBEE komitesi tarafından tanıtılmıştır ve CASBEE UD (Comprehensive Assessment System for Building Environmental Efficiency Urban Development) ismiyle bilinmektedir.

Çalışmanın ikinci bölümde literatür taramasına yer verilmektedir. Öncelikle literatür taraması yapılmış ve ardından çalışmada yer verilen modeller açıklanmıştır. Üçüncü bölümde tesis yeri seçimi problemleri hakkında bilgiler verilmiş ve yer seçim modeli ve geliştirilen model açıklanmıştır. Dördüncü bölümde gerçek hayat uygulaması detaylıca açıklanmıştır. Beşinci bölümde analizden elde edilen bulgular değerlendirilmiştir. Altıncı bölümde sonuç ve gelecekte yapılabilecek çalışmalar hakkında bilgi verilmiştir.

**2. LİTEATÜR TARAMASI**

Bu bölümde öncelikle sürdürülebilir mahalle sertifikasyon sistemleri açıklanmış ve çalışmada yer verilen sertifika sistemi nedenleriyle anlatılmıştır. Ardından tesis yeri seçimi problemi türleri ve uygulamaları açıklanmış ve çalışmada yer verilen problem türleri nedenleriyle açıklanmıştır.

Dünyada yaygın olarak kullanılan sürdürülebilir mahalle sertifikasyon sistemleri DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen E.V), BREEAM (The Building Research Establishment's Environmental Assessment Method), LEED ND (Leadership in Energy and Environment Design Neighborhood Development), GREEN STAR ve GREEN MARK şeklindedir. Bahsedilen sertifika sistemleri arasında yeşil kentsel alan proje tasarımı ve uygulamasına yönelik geliştirilen sertifikasyon süreçleri öne çıkmaya başlamıştır. Literatürde mevcut bu sistemler farklı açılardan değerlendirilmiş ve etkinlikleri üzerine tartışmalar yürütülmüştür. Reith ve Orova (2015) beş UD sisteminin (LEED, CASBEE, BRE'09, BRE'12 ve DGNB) konularına, endekslerine ve göstergelerine göre bir karşılaştırmasını yapmıştır. Bu karşılaştırma, bu araçların sürdürülebilirlik konularını ele almak üzere tasarlanmış olmasına rağmen, sürdürülebilir kalkınmanın belirli alanlarının ya kapsanmadığını ya da yetersiz değindiğini ortaya koymuştur. Ayrıca, DGNB’nin sürdürülebilirlik konuları ve ayrıntılı göstergeler konusunda en kapsamlı olduğu tespit edilmiştir. Öte yandan, CASBEE UD kendine özgü arka planı nedeniyle birçok açıdan farklılık gösterirken, LEED ND ve BREEAM Communities çoğu konuda ortalama bir performans sergilemektedir (Reith ve Orova, 2015). Son olarak Ergönül, Olgun, Tekin, Seçkin, Özgünler, Baççıoğlu, Turgut ve Boso Hanyalı (2023) tarafından SEEB-TR mahalle sertifikasyon sistemi geliştirilmiştir. SEEB-TR mahalle sertifikasyon sistemi, Türkiye'nin kendine özgü koşulları göz önünde bulundurularak özel olarak tasarlanmıştır. SEEB-TR mahalle sertifikasyon sistemi, daha önce kurulmuş olan SEEB-TR (2014) yeşil binalar için Sürdürülebilir Enerji Verimli Binalar (SEEB-TR) sertifikasyon sisteminin bir uzantısı olarak oluşturulmuştur. Bu sistem, sürdürülebilir mahalle değerlendirme sisteminin oluşturulmasında temel teşkil etmiştir.

Literatürdeki pek çok çalışma sürdürülebilir mahalle planlaması yapmak için farklı yöntemler (örneğin; CASBEE UD, LEED ND, BREAAM ve Green Star Communities sertifika sistemleri) kullanmışlardır (Akten ve Kaya, 2022; Akyol ve Şenik, 2019; Bottero, 2015; Camcı, 2022; Çelikyay ve Öztaş, 2018; Ergönül ve diğ., 2023; Gutierrez, 2015; Joss ve Molella, 2013; Küçük, 2022; Odaman Kaya, 2012; Orova ve Reith, 2019; Özdal Oktay ve Özdede, 2012; Sharifi ve Murayama, 2013; Sharifi, 2016; Ünal ve Erol, 2020; Yıldız, Yılmaz, Kıvrak, Aslan ve Gültekin, 2015). Fakat hiçbir araştırmacı sürdürülebilir mahalle planlamasında tesis yeri seçimi problemini dikkate almamış ve mahalle planlamasında sürdürülebilirlik şartlarını sağlayacak tesis yeri seçimini araştırmamıştır. Bu nedenle bu çalışmanın literatüre katkısı tesis yeri seçimi problemi modelini kullanarak sürdürülebilir mahalle planlamasını yapmasıdır. Bu çalışmada kullanılan tesis yeri seçimi probleminin literatürde pek çok türü farklı yöntemler kullanılarak araştırılmıştır (Farahani, Asgari, Heidari, Hosseininia ve Goh, 2012; Chauhan, Unnikrishnan ve Figliozzi, 2019; Laporte, Nickel ve Saldanha-da-Gama, 2019; Wang, Wu, Wang, Zhen ve Qu, 2021; Kahriman, 2021; Soner Kara ve Yurdakul, 2021; Ekiz, Avcı ve Özkale, 2021; Dinç Yalçın, Özsoy ve Taşkın, 2021; Derse, 2022; Dörtköşe, Yazgan ve Ercan Cömert, 2022; Çayır Ervural, 2022; Aydınoğlu, Şişman ve Ergül, 2022; Ercan, Özdilim ve Avcı, 2023; Demirtaş ve Turan, 2023).

Yazarın yaptığı literatür taramasına göre, tesis yeri seçimi modelini kullanan çalışmalar içerisinde çalışmamıza en yakın uygulama olan Çayır Ervural (2022) çalışmasında gıda imalat firmasının ilin içerisinde yer alan satış mağazalarının tesis yer seçimleri için üç aşamalı bir optimizasyon modeli oluşturulmuştur. Çalışma öncelikle küme kapsama problemi kapsamında kurulacak optimum tesis sayısını belirlemiştir. Daha sonra, p-medyan modeli kullanılarak, talep ağırlıklı minimum mesafe amacına dayalı olarak belirli sayıda tesisin konumunu belirlemiştir. Ardından, farklı mesafe kriterlerine (kilometre cinsinden) dayalı olarak kapsanacak alanları belirlemek için maksimum kapsama modeli kullanılmıştır. Modelde, belli sayıda açılacak olan tesis ile bu tesislerden hizmet alacak talep noktası sayısının maksimize edilmesi amaçlanmıştır. Fakat çalışmamızda sürdürülebilir mahalle sertifika sistemlerinde yer alan kriterlerine göre kurulacak minimum sayıdaki tesisin yerlerinin ve mesafe bazlı (metre cinsinden) kapsanacak alanların aynı model üzerinde optimize edilmesi gerekmektedir. Çalışmamızda, gerekli tesis sayısı Çayır Ervural (2022) çalışmasındaki modelden farklı olarak sabit (parametre) değildir, değişken olarak tanımlanmıştır. Literatür taramasının ardından çalışmamızda ihtiyaç duyulan modele en benzer model içsel maksimum kapsama problemidir ve maksimum kapsama problemi türlerinden birisidir. İçsel maksimum kapsama problemi esas olarak kapsanan toplam karşılanan talebi maksimize etmektedir. Bu modelde gerekli olan tesis sayısı parametre olarak modele girilmektedir. Fakat bizim çalışmamızda tesis sayısının değişken olması gerekir. Bu yönüyle model çalışmamızdan ayrışmaktadır.

Bu çalışmanın amacı en temel yerleşim birimi olarak mahallelerin açık yeşil alanları, okul binaları, sivil ve kamu alanlarının yer seçiminin belirlenmesidir. Sürdürülebilir kalkınmayı hızlandırmak için belirli kriterler göz önünde bulundurularak mahalle ölçeğinde bina ve yeşil alan yerleşim planlaması modeli geliştirmiştir. Sürdürülebilir mahalle dönüşümünü gerçekleştirmek isteyen belediyelerin hızlı şekilde hayata geçirmesi için önemli bir adımdır. Bu nedenle literatürde var olan bir model doğrudan çalışmamızda kullanılmamış, bunun yerine yeni bir model geliştirilmiştir. Geliştirilen model, yenilikçi ve etkili sürdürülebilir projelere ihtiyaç duyan kentler için mahalle düzeyinde çözümleri test etme ve entegre etme fırsatı sunmaktadır. Bu modelin gerçek hayata uygulanması, önemli bir katma değer sağlamaya devam ederken hızlı şekilde inovasyona olanak tanımaktadır. Bu nedenle bu çalışmada sürdürülebilir mahalle olarak yakın zamanda kentsel dönüşüme giren ve nazım imar planı hazırlanmış mahaller olan Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahalleri seçilmiştir. Sürdürülebilir mahalle yeşil alan, kamu alanı ve okul binası yer seçimi için çalışmada doğrusal karma tam sayılı programlama (MIP) modeli geliştirilmiştir. Geliştirilen kapsama probleminin matematiksel modeli GAMS 24.1.2 programı yardımıyla çözülmüş ve mahallede açık yeşil alan, kamu alanı ve okul binası olması gereken yeni yerleşimler önerilmiştir.

**3. TESİS YERİ SEÇİMİ PROBLEMİ**

Tesis yeri seçimi problemi ele alınırken, talep ve hizmet noktaları arasındaki mesafe, ihtiyaç duyulan tesis sayısı ve ilgili maliyetler ve ulaşım süresi dâhil olmak üzere çeşitli faktörler göz önünde bulundurulmaktadır. Tesis yeri seçimi problemleri benzerlik gösterse de farklı kısıt veya amaç fonksiyonlarına göre farklı şekillerde ele alınabilmektedir. Literatürde tesis yerleşim problemleri, kareli atama problemi, küme kapsama problemi, maksimum kapsama problemi, sabit maliyetli tesis yerleşim problemi, ana dağıtım üssü yerleşim problemi, maksimum toplam problemi, p-merkez problemi ve p-medyan problemi gibi kapsamlı bir şekilde sınıflandırılmaktadır (Basti, 2012; Daskin, 1995). Çalışmamızda yer seçimi problemi türlerinden olan küme kapsama ve maksimum kapsama problemleri kullanılarak matematiksel model geliştirilmektedir. Bu sebeple öncelikle küme kapsama ve maksimum kapsama problemleri anlatılmaktadır. Sonrasında ise çalışmamıza en yakın olan içsel maksimum kapsama problemi detaylıca açıklanmaktadır.

**3.1. Kapsama Problemleri**

Yer seçimini içeren birçok problemde, müşteriler ile belirlenen tesisler arasındaki yakınlık, hizmetlerin sunulmasında çok önemli bir rol oynamaktadır. Ortalama mesafelerin en aza indirilmesi belirli yer seçimi senaryolarında yaygın bir amaç olsa da, her durumda uygun olmayabilir. Tesis yeri seçimi problemleri, fabrikalar, işletmeler, alışveriş merkezleri gibi ticari kuruluşlar veya okullar, hastaneler ve postaneler gibi kamu kurumları için yer seçimi de dâhil olmak üzere çeşitli konuları kapsamaktadır. Ayrıca, ambulans, itfaiye ve polis birimleri gibi acil durum araçlarının yerleştirilmesini de kapsamaktadır. Örneğin, bir şehirde acil servis araçlarının konumları belirlenirken, talebin anında karşılanması büyük önem taşıdığından, müdahale için maksimum makul bir mesafe veya zaman belirlemek çok önemlidir. Buradaki en önemli faktör kapsama kavramıdır (Owen ve Daskin, 1998). Genel olarak, bir talep düğümü ile tesis arasındaki mesafe kapsama mesafesine eşit veya daha az ise talepler karşılanmış olarak kabul edilmektedir. Kapsama mesafesi tüm talep düğümleri için aynı olabilir veya kapsanan talep düğümlerine ve tesis konumlarına bağlı olarak değişebilir (Daskin, 1995).

Kapsama problemleri; tüm taleplerin kapsanması gereken küme kapsama problemleri (set covering problems) ve taleplerin mümkün olan en yüksek kapsamını elde etmeyi amaçlayan maksimum kapsama problemleri (maximum covering problems) olmak üzere iki şekilde sınıflandırılabilir (Owen ve Daskin, 1998). Kapsama problemlerinin daha iyi anlaşılması için Farahani ve diğ. (2012) çalışması incelenebilir. Küme kapsamı problemi, tüm müşterilere tam kapsama sağlamak için gereken tesis sayısını incelemektedir. Pratik senaryolarda, karar vericiler genellikle istenen kapsama seviyelerinde tesisler kurmak için sınırlı kaynaklarla karşılaşmaktadırlar. Bu gibi durumlarda, yer seçimi probleminin amacı, istenen kapsama mesafesi içinde mümkün olduğunca çok müşteriye ulaşmak için kaynakları kullanmaktır. Bu yeni amaç, maksimum kapsama problemi olarak bilinmektedir. Church ve ReVelle (1974) maksimum kapsama problemi kavramını ilk kez ortaya atmıştır. Maksimum kapsama problemlerinin temel amacı, sabit sayıda tesisin optimum hizmet mesafesini (D\_c) göz önünde bulundurarak maksimum sayıda talebe hizmet vermesidir. Maksimum kapsama problemi türlerinden birisi olan içsel maksimum kapsama problemi esas olarak kapsanan toplam karşılanan talebi maksimize etmektedir. Modelde gerekli olan tesis sayısı parametre olarak girilmektedir. Model, k. seviyede sağlanabilecek kapsamayı en büyüklemektir (Farahani ve diğ., 2012).

**3.2. İçsel Maksimum Kapsama Problemi**

Murray, Tong ve Kim (2010) içsel maksimum kapsama problemi modelini şu şekilde sunmaktadır.

İndisler:

*i*: talep düğümlerinin kümesi

*j*: tesis düğümlerinin kümesi

*k*: kapsama düzeyleri,

Parametreler:

*P*: Gereken toplam tesis sayısı

: *k.* seviyede gerekli minimum kapsama yüzdesi,

: *k.* seviyede tam kapsama için gerekli minimum tesis sayısı,

: *i* düğümündeki talep sayısı (örneğin bu düğümdeki nüfus sayısı) ve

: en az alanını kapsayan potansiyel tesisler kümesi,

Karar değişkenleri:

Model aşağıdaki gibidir:

(1)

Kısıt

(2)

(3)

(4)

(5)

(6)

(7)

Amaç fonksiyonu (1), kapsanan toplam talebi maksimize etmektedir. Kısıt (2), *j.* tesisin atanmasında *i.* talep düğümünün kapsanmasını garanti eder. Kısıt (3), kapsamın *k* düzeyinde sağlanmasını gerçekleştirir. Kısıt (4) toplam tesis sayısını belirtmektedir. Kısıtlar (5)–(7), işaret kısıtlarıdır. İçsel maksimum kapsama probleminde tesis yer seçimi kararı model tarafından belirlenmektedir. Amaç fonksiyonu kapsanan toplam talebi maksimize etmektedir. Toplam tesis sayısı parametre olarak önceden belirlenmektedir (Murray ve diğ., 2010). Gerekli olan tesis sayısının parametre olması sebebiyle çalışmamızda kullanılması istenen modelle örtüşmemektedir. Bu sebeplerle çalışmada yeni bir modelin geliştirilmesi gerekmektedir.

Çalışmada ele alınan gerçek hayat uygulamasında ihtiyacı karşılayacak minimum sayıda yeni tesisin atamasının yapılması gerekmektedir, bu yönüyle küme kapsama problemi özelliği taşımaktadır. Fakat tüm talep düğümlerinin kapsanması gerekmemekte, belirli oranda talep düğümünün kapsanması yeterlidir, bu yönüyle maksimum kapsama problemi özelliği taşımaktadır. Bu sebeple literatürde bilinen küme kapsama problemi ve maksimum kapsama problemi birleştirilerek yeni model geliştirilmektedir. Yeni geliştirilen model karma kapsama problemi matematiksel modeli olarak isimlendirilmektedir.

**3.3. Karma Kapsama Problemi Matematiksel Modeli**

Çalışma kapsamında geliştirilen karma kapsama problemi matematiksel modelinde öncelikle parametrelerin belirlenmesi gerekmektedir. Parametrelerden birisi olan parametresinin belirlenmesi için düğümlerin orta noktaları referans olarak kabul edilmekte ve düğümlerin birbirine uzaklıkları öklid yöntemi kullanılarak hesaplanmaktadır.

Şekil 1’de öklid uzaklık yöntemi örneği verilmektedir. Geliştirilen modelde talep düğümleri ile aday tesisler arasındaki uzaklık şekil 1’de gösterildiği gibi hesaplanarak parametresi olarak girilmektedir.

A black and white diagram with black lines and letters

Description automatically generated with medium confidence

**Şekil 1.** Öklid uzaklık örneği

*Düğüm i* ile *düğüm j* arasındaki uzaklık hesaplanırken öklid uzaklık yöntemi kullanılmaktadır. Öklid uzaklığı formülü Eşitlik (8)’de gösterildiği gibidir.

(8)

Karma kapsama problemi matematiksel modelinin indisleri ve parametreleri aşağıdaki gibidir.

İndisler:

*i*: Talep düğümlerinin kümesi

*j*: Aday tesis yerlerinin kümesi

Parametreler:

*N*: Toplam talep düğümü sayısı

: Tesisleri kapsama oranı

*M*: Çok büyük bir sayı

Karar değişkenleri:

(9)

Kısıtlar:

(10)

(11)

(12)

(13)

(14)

Biçiminde formüle edilebilir.

Eşitlik (9)’da yer alan amaç fonksiyonu, ataması yapılan tesisler için toplam maliyetin en küçüklenmesidir. Eğer tüm *j* aday tesisleri için = 1 olursa veya ataması yapılacak tesis sayısı en küçüklenecekse amaç fonksiyonu şu şekle dönüşmektedir:

(15)

Amaç fonksiyonu amaç fonksiyonu (15)’teki biçiminde sadeleşir.

Kısıt (10), *j.* aday tesis her *i* talep düğümünün en az bir tesis tarafından kapsanmasını sağlar. Kısıtın sol tarafı, *i* talep düğümünü kapsayabilen, yerleştirilmiş tesis sayısını vermektedir. Kısıt (10) doğrusal olmayan yapıdadır. Görüldüğü gibi bu kısıtta ve iki karar değişkeninin çarpımı yer aldığı için doğrusallık bozulmaktadır. *j.* aday yeri *i.* düğümdeki talebi karşılama durumu ve *j.* tesis aday yerine yerleştirilme durumu yer almaktadır. *i.* talep düğümü *j.* aday yerine atanırsa değişkeninin *j.* aday yerine atanmasını garanti eder. Çalışma kapsamında bu kısıt doğrusallaştırılarak yeni kısıt geliştirilmiştir.

(16)

Kısıt (10)’un doğrusallaştırılarak Kısıt (16) haline getirilmesi ile model doğrusal MIP modeli haline dönüşmektedir.

Kısıt (11) kapsama sayısını ifade eder. Bu kısıt çözülen gerçek hayat problemlerinin özelliklerini karşılamak için geliştirilmiştir. Gerçek hayat problemlerinde talep düğümlerinin tümünün bir tesise atanıp bir küme tarafından kapsanması gerekmemektedir. Belirli bir oranda talep düğümünün kapsanması yeterlidir. Kısıt (11), örneğin toplam talep sayısının %50’sinin kapsanması isteniyorsa, *j.* tesise atanan *i.* talep düğümlerinin toplamı toplam talep sayısının %50’sine eşit veya büyük olmasını garanti eder.

Kısıt (12)’de *i* talep düğümü ile aday tesis yeri arasındaki uzaklığın en fazla olmasını sağlar. Kapsama uzaklığı alındığında, için şeklinde gösterilebilir (Drezner ve Hamacher, 2002). Son olarak Kısıt (13) ve Kısıt (14) ise işaret kısıtlarıdır.

Geliştirilen modelin son halinde Eşitlik (15) amaç fonksiyonudur. Kısıt (16), Kısıt (10)’un yerine modelin son halinde yer almaktadır. Kısıt (11), (12), (13), (14) değişikliğe uğramadan modelin son halinde kullanılmaktadır.

**4. UYGULAMA**

Önerilen modelin performansını gösterebilmek için, farklı tesis tiplerini barındıran gerçek hayat problemleri çözülmüştür. Öncelikle bu bölümde uygulama olarak seçilen sürdürülebilir mahalle için yeşil alan, kamu ve sivil alan, okul binası yeri seçimi problemlerinin özellikleri açıklanmıştır. Sürdürülebilir mahalle için yeşil alan, kamu ve sivil alan, okul binalarının yer seçiminde Ankara ilindeki kentsel dönüşüme girmiş tüm mahalleler çalışmanın evrenini temsil etmektedir. Ankara ilindeki kentsel dönüşüm alanlarının belediye meclisi tarafından onaylanmış nazım ve uygulama imar planlarının mahkemeye taşındığı ve durdurma kararları alındığı görülmüştür. Kentsel dönüşüm projesi olarak başlamakta fakat mahkeme tarafından iptal edilmektedir. Bu sebeple tüm kentsel dönüşüme girmiş mahalleler örneklem olarak alınamamıştır. Ankara ilindeki nazım imar planları kesinleşmiş kentsel dönüşüm alanları içerisinden örneklem seçimi yapılmıştır.

“Mahalle Alanın Ölçekli Nazım İmar ve Ölçekli Uygulama İmar Planı ile Bu Alanın İmar Uygulamasının (Parselasyon Planının) Yapma/ Yaptırma İşi” belediyeler tarafından ihale yoluyla uygulamaya geçirilmektedir. Çalışmamız kapsamında da ele alınacak mahallenin nazım imar planının hazırlanmış olması gerekmektedir. Ankara’daki ilçe belediyelerinin imar plan değişiklikleri kesinleşmiş olan nazım imar planlarının erişime açılmaması veya el çizimi imar planlarının okunaklılığının düşük olması gibi sebeplerle örnekleme dâhil edilememiştir. Bahsi geçen sebeplerden dolayı kentsel dönüşüme giren birçok mahalle örneklem olarak alınamamıştır. Bunlardan dolayı örneklem olarak Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahalleri için hazırlanan nazım imar planı çalışmada uygulama alanı (örneklem) olarak seçilmiştir. Şekil 2’de Ankara İli, Keçiören İlçesi, Şenlik, Yakacık, Güçlükaya ve Tepebaşı Mahalleleri konumları detaylı biçimde verilmiştir.

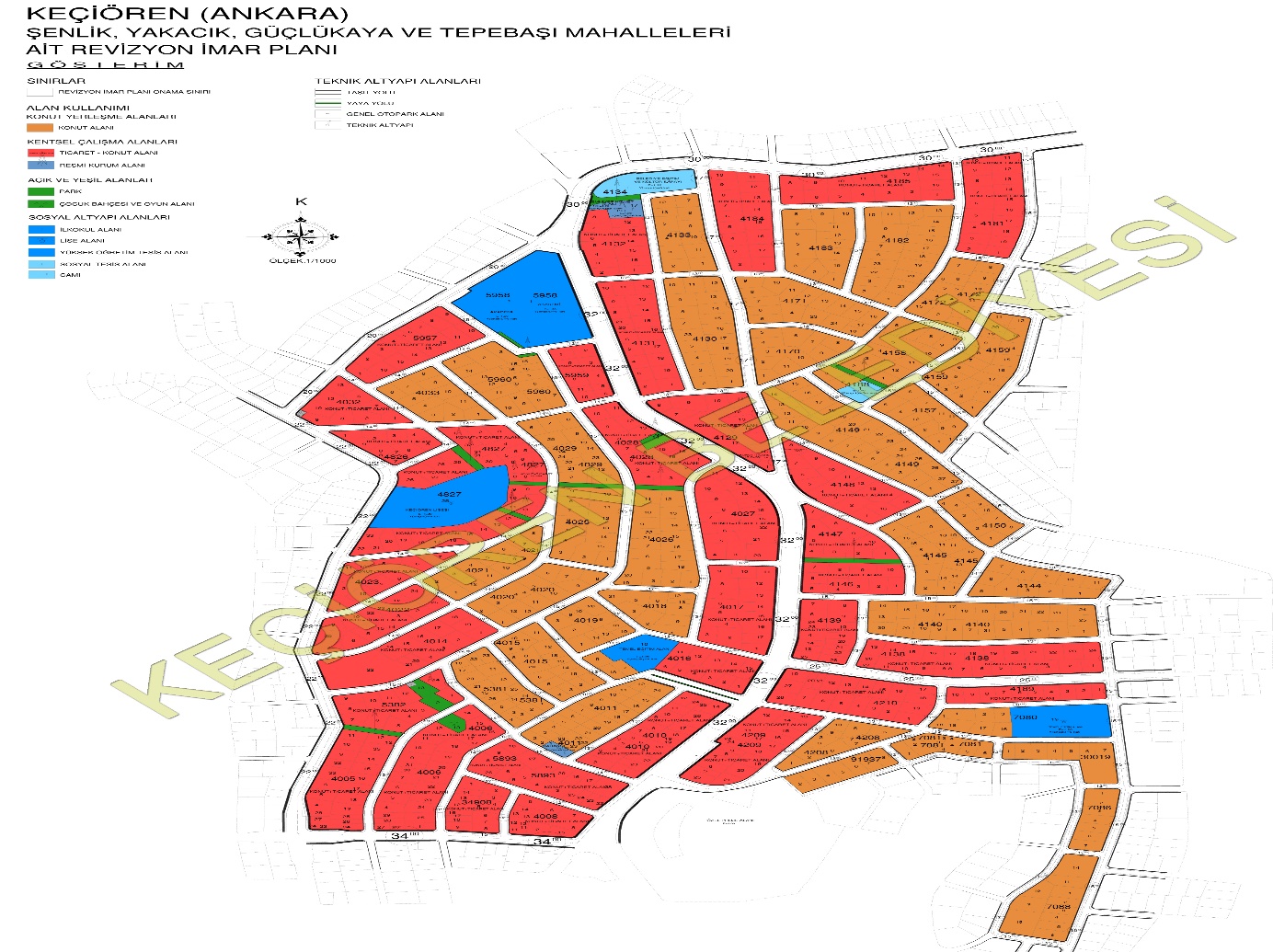
A map of ukraine with a map of ukraine

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**Şekil 2.** Ankara ili, Keçiören ilçesi, Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahallelerinin konumu (yazar tarafından oluşturulmuştur)

Şekil 3’te Keçiören Belediyesi tarafından 2023 yılında hazırlanan Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahallelerin nazım imar planı verilmiştir. Çalışmamız bu imar planı temel alınarak yürütülmüştür. İmar planındaki ada ve parseller numaralandırılmış ve her bir düğümün birbirine öklid uzaklıkları hesaplanmıştır. Matematiksel modelde atamaların yapılmasının ardından yapılan atamalar mevcut nazım imar planı üzerinde gösterilerek yeni yerleşim elde edilmiştir.

Çalışmamızda problemin çözümü için gerekli olan sürdürülebilir mahalle kriterleri olarak sertifika sistemlerinden olan LEED ND referans alınmıştır. Diğer mahalle sertifika sistemlerinin çalışmamızda referans olarak alınmamasının sebebi sistemlerdeki kriterlerin modelimize uygun parametreleri barındırmamasıdır. LEED ND sertifikasında yer alan tüm kriterler çalışmamıza dahil edilmemiştir. Çünkü birçok kriter çalışmamızın kapsamı dışındadır. LEED ND sertifikasında “Mahalle Deseni ve Tasarımı” ana kategorisi altındaki “Rekreasyon İmkânlarına Erişim”, “Mahalle Okulları” ve “Sivil ve Kamusal Alanlara Erişim” alt kriterleri kullanılmıştır. LEED ND sertifikası “Mahalle Deseni ve Tasarımı” ana kategorisi altındaki “Rekreasyon İmkânlarına Erişim” alt kriterine göre mahallede en az 1 dönüm alanda kamuya açık bir açık hava dinlenme tesisi veya en az 2325 m2 alanda kamuya açık bir kapalı dinlenme tesisi, 800 metre mesafe içinde yer alacak şekilde konumlandırılmalı veya tasarlanmalıdır. Yeni ve mevcut konutların ve konut dışı kullanım girişlerinin %90'ı rekreasyon alanlarına yürüme mesafesi ile 800 metre içerisinde yer almalıdır (LEED ND v4, 2018). Bir diğer alt kriter olan “Mahalle Okulları” kriterine göre konut birimlerinin en az %50’si 800 metre mesafede ilkokul veya ortaokul binasına, 1600 metre içerisinde ise en az bir lise binasına erişebilmelidir (LEED ND v4, 2018). Bir diğer alt kriter olan ‘Sivil ve Kamusal Alanlara Erişim’e göre planlanan ve mevcut konut birimlerinin ve konut dışı kullanım girişlerinin %90'ı en az bir sivil ve pasif kullanım alanına 400 metre yürüyüş mesafesinde olmalıdır. Boş alanlar, en az 674 m2 olmalıdır. 1 dönümden daha küçük olan alanlar, 1 birim genişlikten 4 birim uzunluk oranına sahip olmalıdır (LEED ND v4, 2018).Çalışmada ele alınan gerçek hayat problemlerinin çözümünde çalışma kapsamında geliştirilen matematiksel model kullanılmıştır. Her bir örnek uygulamadaki yürüyüş mesafesi değeri parametresi olarak girilmiştir. Son olarak mevcut durumda yeşil açık alan, ilkokul, ortaokul, lise binaları, sivil ve pasif kullanım alanlarının konumları değişkenine sabit değeri “1” olarak atanmış ve değişiklik yapılması engellenmiştir. Diğer değişkenlerine atama yapılmasına imkân tanınmıştır.



**Şekil 3.** Örneklem olarak belirlenen Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahallelerin nazım imar planı (Keçiören Belediyesi, 2023)

**5. BULGULAR**

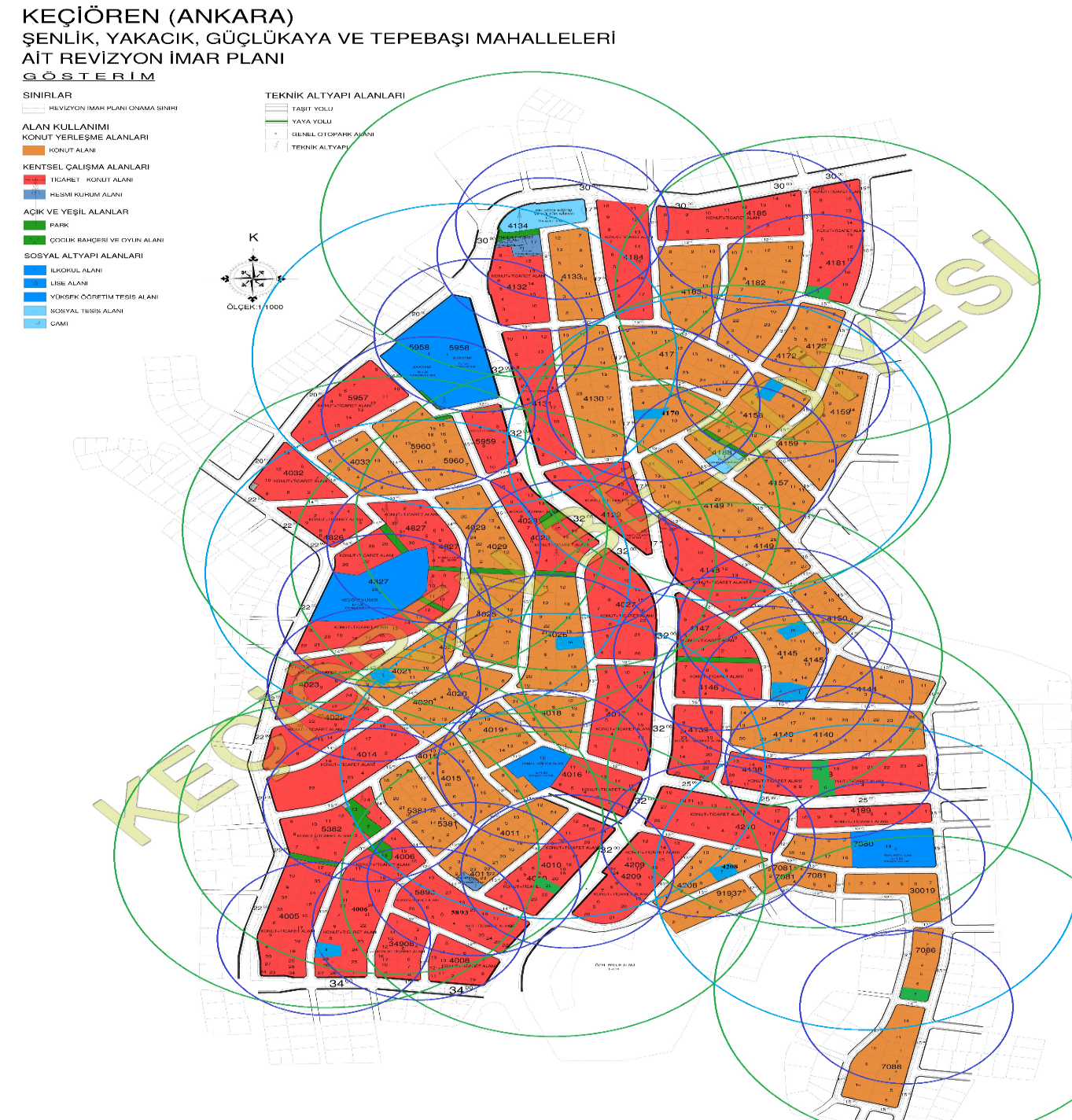
Gerçek hayat uygulaması olarak çalışmada tanımlanan problemler geliştirilen matematiksel model ile GAMS 24.1.2 paket programının CPLEX çözücüsü kullanılarak Intel(R) Core (TM) i7-4702MQ CPU 2.20GHz işlemcisi, 8 GB ram özelliklerine sahip bir bilgisayarda çözülmüştür.

Birinci problemde “Rekreasyon İmkânlarına Erişim” kriteri temelinde örneklemde yer alan yeşil açık alanlar göz önünde bulundurulmuştur. Mevcut mahallelerde 16 dönümlük açık hava rekreasyon alanı bulunmaktadır. Yeşil açık alan olan toplam 16 parselin değişkenine sabit değeri “1” olarak atanmış ve parametresi 800 m yürüme mesafesi değeri olarak girilmiştir. Tüm konumları kapsama oranı olan parametresi 0.90 olarak belirlenmiştir. GAMS programında MIP modeli CPLEX çözücü ile 3.907 saniyede çözülmüştür. İkinci problemde “Mahalle Okulları” kriteri temelinde örneklemde yer alan ilkokul, ortaokul ve liseler göz önünde bulundurulmuştur. Mevcut nazım imar planında Fevzi Altıoğlu İlkokulu, Keçiören Anadolu İmam Hatip Lisesi (kampüs içindeki ilkokul ve ortaokul) ve Keçiören Lisesi (kampüs içindeki ilkokul ve ortaokul) bulunmuştur. Tüm konumları kapsama oranı olan parametresi 0.50 olarak belirlenmiştir. Okulların parsellerinin değişkenine sabit değeri “1” olarak atanmıştır. İlkokul ve ortaokul binası için parametresi 800 m ve lise binası için 1600 m yürüme mesafe değerleri iki farklı modele girilmiştir. GAMS programında MIP modeli CPLEX çözücü ile ilkokul binası modeli 4.188 saniyede ve lise binası modeli 3.969 saniyede çözülmüştür.

Üçüncü problemde “Sivil ve Kamusal Alanlara Erişim” kriteri temelinde örneklemde yer alan yeşil açık alanlar, sivil ve kamusal alanlar göz önünde bulundurulmuştur. Mevcut durumda 16 açık yeşil alan ve 7 kamusal alan en az 1 dönümden oluşmaktadır. Birinci problemde yeni olarak eklenen 5 açık yeşil alan üçüncü probleme dâhil edilmiştir. Toplamda 33 konumun değişkenine sabit değeri “1” olarak atanmış ve parametresi 400 m yürüme mesafesi değeri olarak girilmiştir. Tüm konumları kapsama oranı olan parametresi 0.90 olarak belirlenmiştir. GAMS programında MIP modeli CPLEX çözücü ile 4.063 saniyede çözülmüştür. Her bir problem için elde edilen bulgular aşağıdaki gibidir.

Çalışmada çözülen birinci problemde dört mahalle içerisinde toplamda 16 dönümlük yeşil açık alan bulunmalıdır ve mevcut durumda da 16 dönümlük açık hava rekreasyon alanı bulunmaktadır. Karşılanması gereken bir diğer kriter ise konutların %90’ının 800 metre yürüme mesafesi içerisinde yeşil açık alanlarına veya açık hava rekreasyon alanlarına erişmesinin sağlanmasıdır. Açık yeşil alan modelinin çözümü neticesinde 4010 ada 21 parsel, 4181 ada 2 parsel, 7086 ada 7 parsel, 4138 ada 6 parsel, 4138 ada 18 parsellerine atama yapılmıştır.

Çözülen ikinci problemdeki mahalleler içerisinde yer alan okullara tüm yerleşimlerin %50’sinin 400 metre mesafede erişmesi sağlanmalıdır. Mevcut nazım imar planında Fevzi Altıoğlu İlkokulu, Keçiören Anadolu İmam Hatip Lisesi (kampüs içinde ilkokul ve ortaokul) ve Keçiören Lisesi (kampüs içinde ilkokul ve ortaokul) bulunmaktadır. Öncelikle lise binası modelinin çözümü neticesinde mevcut olan iki lise yeterli gelmekte ve yeni bir lise binasının ataması yapılmamıştır. İlkokul veya ortaokul binası modelinin çözümü neticesinde de yeni bir ilkokul veya ortaokul binası ataması yapılmamıştır. Çözülen üçüncü problemdeki mahalle içerisinde yer alan park alanları yanı sıra sivil ve kamusal alanlara tüm yerleşimlerin %90’ının 400 metre içerisinde erişmesi sağlanmalıdır. Birinci problemde yeni olarak eklenen 5 açık yeşil alan dâhil edilmiştir. Mevcut durumda toplamda 33 konuma sivil ve kamusal alan tesis olarak tanımlanmıştır. Modelinin çözümü neticesinde 4170 ada 3 parsel, 4158 ada 7 parsel, 4145 parsel 1, 4145 parsel 2, 4145 parsel 10, 4026 parsel 16, 4021 parsel 3, 4208 parsel 7 ve 4006 parsel 4 adaylarına sivil veya kamusal alan ataması yapılmıştır. Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahallelerin sürdürülebilir mahalle kriterlerini sağlanması için tesis yeri seçimi yapılan ve mevcutta yer alan açık yeşil alan, ilkokul, ortaokul, lise binaları ve sivil veya kamu alanlarının konumları ve maksimum kapsama alanları Şekil 4’te gösterilmiştir.



**Şekil 4.** Sürdürülebilir mahalle kriterlerini sağlayan mahalle yerleşimi ve yerleşimlerin maksimum kapsama alanları (yazar tarafından oluşturulmuştur)

Şekil 4’te görüldüğü üzere, açık yeşil alanların maksimum kapsama alanları yeşil renkli çemberlerle gösterilmiş ve kapsama alanları tüm yerleşimlerin %90’ını içine almıştır. Benzer şekilde ilkokul, ortaokul veya lise binalarının maksimum kapsama alanları açık mavi renkle gösterilmiş ve kapsama alanları tüm yerleşimlerin %50’sini içine almıştır. Sivil veya kamu alanlarının maksimum kapsama alanları koyu mavi renkle gösterilmiş ve kapsama alanları tüm yerleşimlerin %90’ını içine almıştır.

Çalışmadan elde edilen sonuçlar ile mevcut durumdaki yerleşim karşılaştırıldığında, mevcut durumda açık yeşil alanlar ve sivil veya kamu alanları mahallelerde istenen kapsama alanını karşılamamaktadır. Bu sebeple sürdürülebilir mahalle kriterlerini karşılamamaktadır. Fakat matematiksel modelden elde edilen yeni yerleşimlerin uygulanması ile sürdürülebilir mahalle kriterleri karşılanacağı öngörülmektedir.

**6. SONUÇ**

Bu çalışmada sürdürülebilir mahalle için Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahallerinin yeşil alan, sivil veya kamu alanı ve okul binası yer seçimi incelenmiştir. Gerçek hayat probleminin çözümünde kullanılan model, literatürde bilinen küme kapsama problemi ve maksimum kapsama problemi birleştirilerek geliştirilmiş ve karma kapsama problemi matematiksel modeli olarak isimlendirilmiştir. Model, doğrusal olmayan yapısı sebebiyle doğrusallaştırılmıştır. Modelin çözüm performansını değerlendirebilmek için, üç farklı gerçek hayat problemi geliştirilen modelle çözülmüş ve sonuçlar verilmiştir. Şenlik, Yakacık, Güçlükaya ve Tepebaşı mahalleri için beş parsele açık ve yeşil alan, dokuz parsele sivil veya kamu alanı ataması yapılmıştır. Bu atama yapılan parsellerin bazıları konut alanı, bazıları ise konut + ticari alandır. Kentsel dönüşüme girmiş bu bölgede yeninden yapılaşma olacağı için kamulaştırma yapıldığı takdirde öneriler kolaylıkla uygulamaya konabilir. Sivil veya kamu alanı ataması yapılan parsellere sivil alan olarak ticari tesis kurulması sağlanabilir. Bu sayede sadece beş parselin kamulaştırılması yeterli olabilir. Anayasa'nın 46. maddesinde belirtildiği üzere kamulaştırma kavramı, devletin ve kamu tüzel kişilerinin kamu yararı için gerekli görüldüğünde özel mülkiyete ait arazi veya binaların kısmen veya tamamen zorla el koyulmasıdır. Süreç, bedelin peşin ödenmesi şartı ile izlenecek usul ve esasları belirleyen kanunlarla yönetilmektedir. İdare sadece kendisine verilen kamu hizmetlerini ve teşebbüslerini yürütmek için ihtiyaç duyduğu mallara el koyma konusunda yetkilidir. Kamulaştırma bedeli için yeterli fon tahsis edildikten sonra, yetkili makamlar kamu yararına dayalı bir karar alır (Günday, 2017). Görüldüğü üzere Keçiören Belediyesi kolaylıkla kamulaştırma yapabilir ve önerilen parsellere açık ve yeşil alanları inşa edebilir.

Çalışmanın katkıları aşağıdaki maddelerde belirtildiği gibidir.

* Literatür incelendiğinde tesis yeri seçimi modelleri üretilen test problemleri kullanılarak çözülmekte ve gerçek hayatta karşılaşılan durumlar göz ardı edilmektedir. Bu durumda da gerçek hayat uygulamalarında karşılaşılacak sorunlara yönelik çözümler modeller üzerinde görülememektedir. Bu durum akademik çalışmalarda görülen bir eksiktir. Literatüre katkı sağlanmıştır.
* Çalışmamızda görüldüğü üzere, gerçek hayat uygulaması olması sebebiyle literatürde iki farklı şekilde var olan (küme kapsama problemi ve maksimum kapsama problemi) problemler birleştirilmiş ve yeni bir model geliştirilmiştir. Gerçek hayat uygulaması sayesinde literatüre katkı sağlanmıştır.
* Türkiye’deki mahallelerin sürdürülebilir olabilmesi için gereken kriterlerden olan açık ve yeşil alan, ilkokul, ortaokul ve lise binaları, sivil ve kamusal alan kriterlerinin karşılanması için politikacıların, planlamacıların ve uygulayıcıların faydalanabileceği model geliştirilmiş ve mahalle planlaması uygulamalarına örnek oluşturulmuştur.
* Bu çalışmada, kapsama problemi için doğrusal bir matematiksel model geliştirilmesi literatüre önemli bir katkı sunacağı öngörülmektedir.
* Kentsel dönüşüme giren bölgelerde belediyeler sürdürülebilir mahalle dönüşümü için geliştirilen modeli kullanabilir. Bu sayede önerilen modelin çok sayıda gerçek hayat uygulamasında hayata geçirilebileceği düşünülmektedir.

Çalışmamızda kısıtlılık olarak literatürdeki sadece iki tesis yerleşim problemi türünün kullanılmasıdır. Farklı gerçek hayat problemlerinin doğası gereği geliştirilen model yetersiz gelebilir ve diğer problem türlerini içeren yeni modellerin geliştirilmesi gerekebilir. Bu sebeple gelecek araştırmalarda literatürde yer alan ve çalışma kapsamında kullanılmayan kareli atama problemi, sabit maliyetli tesis yerleşim problemi, ana dağıtım üssü yerleşim problemi, maksimum toplam problemi, p-merkez problemi ve p-medyan problemi türleri kullanılarak sürdürülebilir mahalle kriterlerine göre yeni matematiksel modeller geliştirilebilir.

Çalışmamızdaki bir diğer kısıtlılık örneklemin dar olmasıdır. Örneklemin dar olması sebebiyle çok daha verimli sonuçlar elde edilmesi sağlanamamıştır. Bu sebeple gelecek çalışmalarda geliştirilen model kullanılarak daha büyük örneklem olarak farklı mahaller çözülebilir. Bu sayede geliştirilen modelin performansı değerlendirileceği düşünülmektedir.Çalışmamızdaki bir diğer kısıtlılık ise Küme kapsama problemi ve maksimum kapsama problemi NP-Zor sınıfında yer almasıdır (Al-Sultan, Hussain ve Nizami, 1996). Bu nedenle sıklıkla sezgisel ve arama algoritmaları kullanılarak ele alınmaktadır (Chvatal, 1979). Görüldüğü üzere, geliştirilen modelin daha büyük örneklemde kesin çözüm algoritmaları ile çözülmesi mümkün değildir. Sezgisel veya meta sezgisel algoritmalar modelin çözülmesi için kullanılabilir.

**ÇIKAR ÇATIŞMASI**

Yazar herhangi bir çıkar çatışması olmadığını beyan etmiştir.

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**KAYNAKLAR**

Akten, S. ve Kaya, L. G. (2022). *Isparta Çünür Mahallesinin LEED Mahalle Gelişim Kriterleri Kapsamında İncelenmesi.* (Ed. Murat Dal), *Mimarlık, Planlama ve Tasarım Alanında Gelişmeler* (s.105-133) İçinde, Ankara: Duvar Yayınları.

Akyol, D. ve Şenik, B. (2019). Sürdürülebilir Mahalle Ölçeğinde Yerele Özgü Bir Setifikasyon Sistemi: Trabzon Konaklı Örneği . Artium, 7 (1), 1-11. Erişim adresi: <https://artium.hku.edu.tr/tr/pub/issue/43057/428967>

Al-Sultan, K.S., Hussain, M.F. ve Nizami, J.S. (1996). A genetic algorithm for the set covering problem. *Journal of the Operational Research Society*, 47(5), 702-709. Erişim adresi: <https://doi.org/10.1057/jors.1996.82>

Aydınoğlu, A. Ç., Şişman, S. ve Ergül, İ. (2022). Sezgisel Ağ Tabanlı Konum Tahsis Analiz Algoritmaları ile Tesis Yeri Optimizasyonu: İtfaiye Tesisleri Yer Seçimi Örneği. *Journal of Turkish Operations Management,* 6 (1), 955-976. Erişim adresi: <https://dergipark.org.tr/tr/pub/jtom/issue/70951/962890>

Basti, M. (2012). P-medyan Tesis Yeri Seçim Problemi ve Çözüm Yaklaşımlar. *Online Acad. J. Inf. Technol.,* 3(7), 47-75. [https://doi.org/10.5824/1309- 1581.2012.2.004.x](https://doi.org/10.5824/1309-%201581.2012.2.004.x)

Bottero, M. (2015). A Multi-Methodological Approach For Assessing Sustainability Of Urban Projects. *Management Of Environmental Quality An International Journal,* 26 (1), 138–154. <https://doi.org/10.1108/MEQ-06-2014-0088>

Brundtland Report (1987). 1987: Brundtland Report. Erişim adresi: <https://www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html>

Camcı, A. (2022). Sürdürülebilir Mahalle Olarak Sivas İstiklal Mahallesinin LEED ND Sertifikasyon Kriterlerine Göre Değerlendirilmesi. *Journal of Social, Humanities and Administrative Sciences*, 8(57),1457-1479. <http://dx.doi.org/10.29228/JOSHAS.65076>

Chauhan, D., Unnikrishnan, A. & Figliozzi, M. (2019). Maximum coverage capacitated facility location problem with range constrained drones. *Transportation Research Part C: Emerging Technologies,* 99, 1–18. <https://doi.org/10.1016/j.trc.2018.12.001>

Choguill, C. L. (2008). Developing Sustainable Neighbourhoods. *Habitat International*, 32, 41-48. <https://doi.org/10.1016/j.habitatint.2007.06.007>

Church, R. & ReVelle, C. (1974) Maximal Covering Location Problem. *Papers of the Regional Science Association,* 32, 101-118. <https://doi.org/10.1007/BF01942293>

Chvatal, V. (1979). A greedy heuristic for the set-covering problem. *Mathematics of operations research,* 4(3), 233-235. <https://www.jstor.org/stable/3689577>

Coppin P., Jonckheere I., Nackaerts K. & Muys B., (2004). Digital change detection methods in ecosystem monitoring. *Int. J. Remote Sensing*, 25(9), 1565-1596. <https://doi.org/10.1080/0143116031000101675>

Çayır Ervural, B. (2022). Çok Aşamalı Yer Seçim Modelleriyle Satış Mağazası Yerinin Belirlenmesi: Konya Örneği. *International Journal of Advances in Engineering and Pure Sciences,* 34 (4), 489-503. <https://doi.org/10.7240/jeps.1085547>

Çelikyay, S. ve Öztaş, R., G. (2018). LEED ND Yeşil Sertifika Sistemleri Bağlamında Ekolojik Mahalle Tasarımı. *International Eurasian Conference On Science, Engineering and Technology,* 2031-2038, Ankara. Erişim adresi: <https://www.researchgate.net/publication/329799909_ND_yesil_sertifika_sistemleri_baglaminda_ekolojik_mahalle_tasarimi>

Daskin, M.S. (1995). *Network and Discrete Location, Models, Algorithms, and Applications*. Hoboken: John Willey & Sons Ltd. <https://doi.org/10.1002/9781118537015>

Demirtaş, M. ve Turan, A. (2023). Muğla ili 112 acil sağlık istasyonlarının optimizasyonu. *Turkish Studies - Economy*, 18(1), 97-107. Erişim adresi: <https://dx.doi.org/10.7827/TurkishStudies.66107>

Derse, O. (2022). Dematel Tabanlı TOPSIS Yöntemi Ve Küme Kapsama Modeli İle Afet Lojistiği İçin Depo Yeri Seçimi: Ege Bölgesi Örneği. *Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi,* 25 (4), 702-713. <https://doi.org/10.17780/ksujes.1159925>

Dinç Yalçın, G., Özsoy, C. Y., & Taşkın, Y. (2021). A multi-objective mathematical model for the electric vehicle charging station placement problem in urban areas. *International Journal of Sustainable Energy,* 41(8), 945-961. <https://doi.org/10.1080/14786451.2021.2016761>

Dörtköşe, S., Yazgan, H. R. ve Ercan Cömert, S. (2022). Elektrikli Araç Şarj İstasyon Yerlerinin Akış Yakıt İkmal Yer Modeli Kullanılarak Belirlenmesi. *Erciyes Üniversitesi Fen Bilimleri Enstitüsü Fen Bilimleri Dergisi*, 38 (2), 371-382. Erişim adresi: <https://dergipark.org.tr/tr/pub/erciyesfen/issue/72216/1113808>

Drezner Z. & Hamacher, H. (2002). *Facility Location: Applications and Theory.* Berlin: Springer-Verlag. Erişim adresi: <https://link.springer.com/book/9783540421726>

Ekiz, M. K., Avcı, S., ve Özkale, C. (2021). Sürekli Uzayda Tesis Yeri Seçimi İçin Matematiksel Model: p-Medyan Problemi. *Avrupa Bilim ve Teknoloji Dergisi,* 28, 386-390. <https://doi.org/10.31590/ejosat.1001560>

Ercan, B., Özdilim, S., ve Avcı, M. G. (2023). Orman yangınlarına ilk müdahale ekiplerinin yerleşim planlaması: Aliağa-İzmir örneği. *Anadolu Orman Araştırmaları Dergisi,* 9 (1), 96-103. <https://doi.org/10.53516/ajfr.1259506>

Ergönül, S., Olgun, İ., Tekin, Ç., Seçkin, N.P., Özgünler, M., Baççıoğlu, C., Turgut, E. & Boso Hanyalı, Ö. (2023). Development of A Neighborhood Sustainability Assessment System for Turkey: SEEB-TR Neighbourhood, *Planlama,* 33(1),105–122. <https://doi.org/10.14744/planlama.2022.35683>

Farahani, R. Z., Asgari, N., Heidari, N., Hosseininia, M., & Goh, M. (2012). Covering problems in facility location: A review, *Computers & Industrial Engineering*, 62, 368- 407. <https://doi.org/10.1016/j.cie.2011.08.020>

Gutierrez, E.E. (2015). *Collaborative Neighborhood-Scale Sustainability Assessment And Planning Using The Spatial Optimization For Urban Resource Conservation And Engagement (SOURCE) Tool: Applying The Analytic Hierarchy Process For Spatial Decision Support* (Doktora tezi). Erişim adresi: <https://ir.library.oregonstate.edu/concern/graduate_thesis_or_dissertations/qb98mk02m>

Günday, M. (2017). *İdare Hukuku* (11. Baskı). Ankara: İmaj Kitabevi.

Jickling, B. (1994). Studying Sustainable Development: Problems and Possibilities. *Canadian Journal of Education/Revue canadienne de l'éducation*, 19(3), 231-240. <https://doi.org/10.2307/1495129>

Joss, S., & Molella, A.P. (2013). The Eco-City As Urban Technology: Perspectives On Caofeidian International Eco-City (China). *Journal Of Urban Technology,* 20(1), 115–137. <https://doi.org/10.1080/10630732.2012.735411>

Kahriman, B. (2021). *İnsansız hava aracı (İHA) ve insansız su aracı (İSA) baz istasyonlarının kara ve su altı ağlarda maksimum kapsama sağlayacak şekilde yerleşimi.* (Yüksek Lisans Tezi). Erişim adresi: <https://gcris.etu.edu.tr/handle/20.500.11851/7859>

Keçiören Belediyesi (2023). İmar Plan Değişikliği (Şenlik, Yakacık, Güçlükaya ve Tepebaşı) Erişim adresi: <https://www.kecioren.bel.tr/imar_plan_degisikligi__senlik__yakacik__guclukaya_ve_tepebasi__-264-duyuru.html>

Küçük, M. (2022). *Sürdürülebilir Kentsel Dönüşüm: Leed-Nd Ölçütleri Bağlamında İstanbul Metropolitan Alanında ‘Piyalepaşa İstanbul’ Ve ‘Bayrampaşa Eski Cezaevi’ Kentsel Dönüşüm Projelerinin Değerlendirilmesi*. (Yüksek Lisans Tezi). <https://tez.yok.gov.tr> veri tabanından erişildi (Tez No. 733647).

Laporte, G., Nickel, S., & Saldanha-da-Gama, F. (2019). *Introduction to Location Science*. In: Laporte, G., Nickel, S., & Saldanha da Gama, F. (eds) *Location Science*. Springer, Cham.

LEED ND v4 (2018). LEED v4 for Neighborhood Development - current version Erişim adresi: <https://www.usgbc.org/resources/leed-v4-neighborhood-development-current-version>

Mc Cormick, K. (2013). Advancing Sustainable Urban Transformation, *Journal of Cleaner Production,* 50, 1-11. <https://doi.org/10.1016/j.jclepro.2013.01.003>

Meadows D. H.; Meadows D. L. Randers, J.& Behrens W., W. III. (1972). The Limits to Growth, Universe Book, New York. <https://www.clubofrome.org/publication/the-limits-to-growth/>

Murray, A. T., Tong, D., & Kim, K. (2010). Enhancing classic coverage location models. *International Regional Science Review,* 33(2), 115–133. <https://doi.org/10.1177/0160017609340149>

Ng, M. K., Cook, A. ve Chui, E. W. T. (2001). The Road Not Travelled: A Sustainable Urban Regeneration Strategy for Hong Kong. *Planning Practice&Research,* 16(2), 171-183. Doi: <https://doi.org/10.1080/02697450120077370>

Odaman Kaya, H. (2012). *Ölçütlere Dayalı Değerlendirme ve Sertifika Metotlarından LEED ve BREEAM'in Türkiye Uygulamalarına Yönelik İrdeleme ve Öneriler*. (Yüksek Lisans Tezi). <https://tez.yok.gov.tr> veri tabanından erişildi (Tez No. 307115).

Orova, M., & Reith. (2019). Multiscalarity in International Sustainable Assessment Systems: A Qualitative Comparison of LEED, CASBEE, BREEAM, DGNB and ESTIDAMA on Building, Neighbourhood and City Scale. *IOP Conference Series: Earth and Environmental Science,* 290, 012056. <https://doi.org/10.1088/1755-1315/290/1/012056>

SEEB-TR (2014). Yapılarda Enerji Verimliliği Araştırma-Geliştirme, Bilgi Paylaşım Sisteminin Oluşturulması Projesi, ISTKA BIL-74. Erişim adresi: <https://www.academia.edu/4729960/Yap%C4%B1larda_Enerji_Verimlili%C4%9Fi_Ara%C5%9Ft%C4%B1rma_Geli%C5%9Ftirme_Bilgi_Payla%C5%9F%C4%B1m_Sisteminin_Olu%C5%9Fturulmas%C4%B1_Projesi_S%C3%BCrd%C3%BCr%C3%BClebilir_Enerji_Etkin_Binalar_Sustainable_Energy_Efficient_Buildings_SEEB_Tr_Sertifika_Sistemi>

Owen, S. H. & Daskin, S. M. (1998). Strategic facility location: A review, *European Journal Of Operational Research*, 111(3), 423–447. <https://doi.org/10.1016/S0377-2217(98)00186-6>

Özdal Oktay, S. ve Özdede, S. (2012). Mevcut Mahallelerin Dönüşümünde Yerele Özgü Çevresel Değerleme Metotlarının Karşılaştırılması. *Dünya Şehircilik Günü 36. Kolokyumu,* 217-231, Ankara. Erişim adresi: <https://www.researchgate.net/publication/277639105_MEVCUT_MAHALLELERIN_DONUSUMUNDE_YERELE_OZGU_CEVRESEL_DEGERLEME_METOTLARININ_KARSILASTIRILMASI>

Reith, A., & Orova, M. (2015). Do green neighbourhood ratings cover sustainability? *Ecological Indicators,* 48, 660-672. [https://doi.org/10.1016/j. ecolind.2014.09.005](https://doi.org/10.1016/j.%20ecolind.2014.09.005)

Roberts, P. (2008). *The Evulotion Definition and Purpose of Urban Regeneration.* Roberts P., Sykes H. (Ed.), Urban Regeneration a Handbook (9-37), London: Sage Publication.

Rohe, W. (2009). From Local To Global: One Hundred Years Of Neighborhood Planning. *Journal Of The American Planning Association,* 75(2), 209–230. <https://doi.org/10.1080/01944360902751077>

Sharifi, A. (2016). From Garden City To Eco-Urbanism: The Quest For Sustainable Neighborhood Development. *Sustainable Cities and Society*, 20, 1–16. <https://doi.org/10.1016/j.scs.2015.09.002>

Sharifi, A., & Murayama, A. (2013). A Critical Review Of Seven Selected Neighborhood Sustainability Assessment Tools. *Environmental Impact Assessment Review,* 38:73–87. <https://doi.org/10.1016/j.eiar.2012.06.006>

Soner Kara, S. ve Yurdakul, G. (2021). Raylı Sistem İstasyon Yeri Belirleme Problemi İçin Küme Kapsama ve Alternatif Servis Seviyeli P-Medyan Modelleriyle Çözüm Arayışı: Gebze-Darıca Metro Hattı Uygulaması. *Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi,* 23 (69), 845-856. <https://doi.org/10.21205/deufmd.2021236912>

Tang, B.S. (2002). *From Privatization to Bureaucratization: Implementing Urban Renewal in Hong Kong.* Thornley A. & Rydin Y. (ed), Planning in a Global Era (307-325). UK: Ashgate, Aldershot.

Ünal, S. G., & Erol. D. (2020). The Variation of Sustainable Neighborhood Planning, Planning New Trends “Ecodistrict” Approaches and its Application in Turkey. *Planning*. 30(1), 15-35. <https://doi.org/10.14744/planlama.2019.27676>

Wang, W., Wu, S., Wang, S., Zhen, L., & Qu, X. (2021). Emergency facility location problems in logistics: Status and perspectives. *Transportation Research Part E: Logistics and Transportation Review*, 154, 102465. <https://doi.org/10.1016/j.tre.2021.102465>

Yıldız, S., Yılmaz, S., Kıvrak, S., Aslan, G., ve Gültekin, A.B. (2015). Mahalle Sürdürülebilirlik Değerlendirme Sistemlerine Yönelik Bir İnceleme Çalışması, *1. Uluslararası Mimarlık ve Tasarım Kongresi,* 1-20, Kocaeli. Erişim adresi: <https://www.researchgate.net/publication/309512809_MAHALLE_SURDURULEBILIRLIK_DEGERLENDIRME_SISTEMLERINE_YONELIK_BIR_INCELEME_CALISMASI>

**Examining Quality Challenges in Small and Medium-Sized Enterprises (Smes) in Ankara: Applying The 5s Methodology**

Melike Nur Tek1, İrem Özkan2, Melek İlarslan3, Deniz Efendioğlu4

1, 2, 3 Industrial Engineering, Faculty of Engineering & Natural Science, Ankara Yıldırım Beyazıt University, Ankara, Turkey

4 Industrial Engineering, Faculty of Engineering & Natural Science, Ankara Yıldırım Beyazıt University, Ankara, Turkey

ORCID No: https://orcid.org/0000-0002-3710-9187

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| --- | --- | --- |
| **Keywords** | | **Abstract** |
| *SMEs in Turkey; 5S; Lean Production; Non-Parametric Tests* | | *The primary focus of this research revolves around addressing quality-related challenges and management issues within small and medium-sized enterprises (SMEs) in Turkey. SMEs constitute a significant portion of the country's total business landscape and therefore exert a substantial influence on its economy. However, the relatively low level of quality consciousness among SMEs has resulted in a variety of problems. Thankfully, the simple and straightforward 5S quality methodology can serve as an effective solution to these issues. The 5S method proves invaluable for enhancing overall quality and optimizing operational processes. To gain deeper insights into the current state of SMEs regarding quality problems and awareness, conducted a survey specifically targeting manufacturing SMEs in Ankara. We carefully analyzed the responses from fifty SMEs based in Ankara using non-parametric hypothesis tests. The primary factors contributing to these quality problems include inadequately trained employees, insufficient quality education or training, and a general disregard for overall quality. In this context, quality managers assume a critical role in adequately training their workforce and fostering a heightened sense of quality awareness. By increasing awareness and implementing the future research plans outlined in this study, the 5S methodology can potentially pave the way for Turkish SMEs to transition into high-quality production processes.* |
| Research Article |  | | |
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**1. INTRODUCTION**

The number of SMEs increased drastically in 2020, SMEs accounted for 99.8% of the total number of companies in Turkey “Against that; 72% of employment and 49.4% of turnover” (TÜİK, 2020).

[[3]](#footnote-3)

The numbers of SMEs are shown in Figure 1, with details distinguishing between micro, small, and medium enterprises. It is obvious that the SMEs in Turkey are playing a dominant role for the economic development of the country. The export values for different types of SMEs can be observed in Figure 2. In that case, Quality Management is very important, not only for meeting the customers’ requirements but also for meeting the organization’s requirements. In general, Quality Management has many advantages like, reducing waste, reducing the costs, and increasing the profits, preventing mistakes and failures, reducing risks, and increasing overall efficiency and productivity. But the small to medium enterprises in Turkey have many gaps and weaknesses in Quality Management. It is found that SMEs in Turkey have a knowledge gap in implementing any Quality management tool and philosophy. According to the research made, there is a lack of existing literature about 5S implementation on SMEs in Turkey. Another issue to consider is the low-Quality importance awareness of Small and medium-sized enterprises in Turkey.

metin, çizgi, öykü gelişim çizgisi; kumpas; grafiğini çıkarma, ekran görüntüsü içeren bir resim

Açıklama otomatik olarak oluşturuldu

**Figure 1.** Change in number of smes in turkey over years (tuik, 2020)

The purpose of this research is, to show the importance of Quality Management and what can be achieved by implementing a Quality philosophy like 5S on SMEs. Given the lack of quality knowledge of SMEs, the goal of this paper is to show that 5S is the easiest and most effective method to increase the overall quality.

çizelge içeren bir resim

Açıklama otomatik olarak oluşturuldu

**Figure 2.** Export values of enterprises by sector and size ($ million)

Furthermore, the motivation for this research arises from the current situation of the SMEs in Turkey, where many SMEs have prejudices that the implementation is a big, expensive, time-consuming, and laborious change and don't know the actual advantages of Quality improvement tools.

**Figure 3.** General framework

The aim of this paper is, to clarify all the prejudices of SMEs, to increase the quality importance awareness and to prove that 5S is a very suitable and simple philosophy for all SMEs. In order to realize all of this, a survey is used to critically analyze and evaluate quality awareness and quality problems in SMEs based in Ankara. Also, the 5S methodology is analyzed in detail and illustrated applicable to all SMEs. This research is intended to help Turkish SMEs having a simple but effective solution to their quality problems. The general framework of the study can be seen from Figure-3.

**2. LITERATURE REVIEW**

**2.1. Implementations of 5S in SME’s**

Systematically introducing and implementing the 5S method means for SMEs that they choose the path to more customer satisfaction, higher work efficiency and more effective collaboration in orders and projects. The graph of quality knowledge of SME’s from literature and this study ca be observed by Figure-4. Soumya R. Purohit and V. Shantha agreed that 5S provides one of the most important foundations for realizing lean manufacturing (Purohit & Shantha, 2015). Furthermore, there is an assumption that 5S is just good housekeeping and only clean and tidy, but James Van Patten makes it clear that 5S is a way of changing the way people do their work, their workplace and addressing each other and, provides the basis for significant improvements (Van Patten, 2006). In their study, H. R. Zadry and R. Darwin demonstrated an increase in productivity after the application of 5S and PDCA to a handmade shoe producing SME in West-Sumatra (Zadry & Darwin, 2020). Another research is from India, Prof. Saad Shaikh and his colleagues implemented the 5S method on a small-scale filter production company (Shaikh et. al., 2015). Furthermore, Paloma Martínez Sánchez and Carolina Montoya Rodriguez studied in 2015 about the impacts of 5S on quality, productivity, and organizational climate and also Avishkar A. Ahire and his colleagues make a study of the 5S method at a manufacturing company also in India (Sanchez et. al.,2015), (Ahire & Ahirrao, 2021). Lately, In 2020, Mohd Adzrie and T. Vincent, implemented the 5S on a SME in Malaysia, where they planned the implementation with the PDCA Cycle (Radzali & Thomas, 2020).

When the successful studies are examined, Agrahari et. al. (2015) states the implementation of the 5S methodology in a small-scale industry, demonstrating significant improvements in safety, productivity, efficiency, and housekeeping by visual evidence. Another study is Ezzeddine & Aoun’s (2019) study revealed a notable and favorable impact of 5S on employee performance across all aspects except for the "Sort" stage. Sangode (2018) stated in her research findings indicating that organizations experience a beneficial outcome from implementing the 5S methodology. Also critiqued studies can be observed from literature. Mishra & Chakraborty (2014) introduces a lean implementation model that is notably generic and has effectively addressed numerous challenges associated with implementation, distinguishing it from other frameworks. Unlike industry-specific approaches, the identified lean implementation frameworks discussed in the paper exhibit a broader applicability, making them adaptable across various sectors. Gala & Wolniak (2013) furnishes theoretical explanations of Lean Management and 5S, accompanied by a case study derived from practical insights. Furthermore, the author details the issues encountered during the implementation of 5S.

**Figure 4.** Quality knowledge of SMEs

**2.2. Barriers in Implementation of 5S**

While some enterprises lack knowledge about the 5S method, some enterprises have a bias towards the 5S methodology due to the unsuccessful results they had achieved with wrong or incomplete implementation on their previous initiatives, and this has led to the opinion that the 5S method is an ineffective tool. Gala and Wolniak applied the 5S methods in an enterprise both in production and in the office and examined the obstacles they encountered during the application (Gala & Wolniak, 2013). Furthermore, Rahman, Khamis, Zain, Deros, and Mahmood developed a questionnaire to measure the level of implementation of the 5S. As a result of the survey, it was tried to measure the performance of using 5S tools in different divisions of two different businesses by using a Likert scale, and the problems faced while performing 5S practices are examined (Rahman et. al., 2010). Another study for the determination of the barriers for 5S is Nilipour and Jamshidian’s study that 5S applications are an important and powerful tool for environmental organization management and discussed the obstacles to the effective implementation of 5S (Akbar & Mehdi, 2005). From the perspective of employees Titu, Oprean, Grecu implemented Kaizen-5S in the after-sales department of a business and analyzed the results (Titu et. al., 2010). Ramdass have conducted a study on the implementation of 5S in clothing and textile industry using case study methodology. It is pointed out that the main problem in the implementation of the 5S method is the resistance of the employees to change (Ramdass, 2015).

**3. METHODOLOGY**

A survey was conducted to measure how much SMEs know about the concept of quality, their attitudes about quality activities and their level of application of these activities, and to evaluate their knowledge and inclinations about the 5S method. In this survey study, manufacturing SMEs located in Ankara were selected as the target population. According to the industry registry records of the Ministry of Science, Industry and Technology, Ankara ranks 3rd in terms of industry share in Turkey. In this respect, Ankara province is considered as a suitable population in terms of representing all SMEs in Turkey. According to 2019 data, the number of industrial enterprises in Ankara is 11700 and the number of SMEs is 11587. Under the condition of the difference (0.2), estimated standard deviation (0.5), and the target power (0.80), it is found that a sample size of approximately 50 is sufficient for Ankara province. In order to implement the survey, at the stage of reaching SMEs, data such as the names and contact information of SMEs operating in the province of Ankara were requested from KOSGEB through an official letter. However, upon the negative response, the businesses were searched one by one through the company lists on the websites of the organized industrial zones in Ankara, and the contact addresses of the businesses that were determined to be SMEs were reached. The survey had been sent to between 300-400 companies. First of all, businesses were contacted via e-mail and data was started to be collected via Google Forms, then the survey study was continued by reaching business officials via social media. Since the desired number could not be reached by these means, the survey continued with face-to-face interviews held in OSTİM industrial area and the survey was completed by reaching 50 enterprises. The sample size would like to be enhanced; however, the answers of survey are not taken from the SMEs in the period of 6 months except for fifty-one.

The survey consists of 2 parts and 35 questions in total. In the first part of the survey, general questions about the business such as the duration of the business, the number of employees, the existence of the quality department or personnel were included. The second part consists of 21 questions using a 5-point Likert Scale. In this section, it has been tried to understand the quality awareness of the enterprises and their attitudes in applying and maintaining quality activities, and in the last 5 questions, it is aimed to determine their predisposition to 5S by questioning the factors such as order and cleanliness in the enterprises. The data obtained from the questionnaire were interpreted statistically by hypothesis tests. Statistical tests are often subdivided into parametric tests on the one hand and non-parametric tests on the other. Parametric tests have higher test power than non-parametric tests, but there are some assumptions that must be met in order to be applied. These assumptions are data conforming to normal distribution, data being interval or ratio scaled, homogeneous variances, knowing the main population parameters, and sufficient number of subjects in the groups. Non-parametric tests are used when the metric scale level is not available, the true distribution of random variables is unknown, the variables are nominal or ordinal scaled, and the sample is not large enough. Since the data obtained from the questionnaire have nominal and ordinal scales, non-parametric hypothesis tests were used in this study. According to the number of group variables in the sample, the appropriate one from the Mann-Whitney U and Kruskal Wallis tests was selected, and the hypotheses were tested at the 95% confidence interval. The hypothesis has been given at Table-1 in detail.

**Table 1.** Hypothesis Tests

|  |  |
| --- | --- |
| **1** | H0= There is no significant difference between the business scale and the tendency to 5S.  H1= There is a significant difference between the scale of the enterprise and the tendency to 5S. |
| **2** | H0= There is no significant difference between the age of the business and the tendency to 5S.  H1= There is a significant difference between the age of the business and the tendency to 5S. |
| **3** | H0= There is no significant difference between the existence of the quality department and the quality training which is given or not.  H1= There is a significant difference between the existence of the quality department and the quality training which is given or not. |
| **4** | H0= There is no significant difference between the scale of the enterprise and the application of the quality method.  H1= There is a significant difference between the scale of the enterprise and the application of the quality method. |
| **5** | H0= There is no significant difference between the age of the enterprise and the application of the quality method.  H1= There is a significant difference between the age of the enterprise and the application of the quality method. |
| **6** | H0= There is no significant difference between the age of the enterprise and the knowing of the 5S method.  H1= There is a significant difference between the age of the enterprise and the knowing of the 5S method. |
| **7** | H0= There is no significant difference between the scale of the enterprise and the knowing of the 5S method.  H1= There is a significant difference between the scale of the enterprise and the knowing of the 5S method. |
| **8** | H0= There is no significant difference between the fact that mistakes are caused by lack of information and employees are informed about products, processes, workflow, quality requirements, etc.  H1= There is a significant difference between the fact that mistakes are caused by lack of information and employees are informed about products, processes, workflow, quality requirements, etc. |
| **9** | H0= There is no significant difference between the errors caused by the lack of knowledge and who has the responsibility for quality.  H1= There is a significant difference between errors caused by lack of knowledge and who has the responsibility for quality. |
| **10** | H0= There is no significant difference between the fact that the errors are caused by the supplier and that the selection of suppliers is the number one criterion for SMEs.  H1= There is a significant difference between the fact that the faults originate from the supplier and that the supplier selection is the number one criterion for SMEs. |
| **11** | H0= There is no significant difference between the fact that the errors are caused by the employee, and the quality training is given to the employees.  H1= There is a significant difference between the fact that the errors are caused by the employee, and the quality training is given to the employees. |
| **12** | H0= There is no significant difference between the infrastructure-related faults and the age of the enterprise.  H1= There is a significant difference between the infrastructure-related errors and the age of the enterprise. |
| **13** | H0= There is no significant difference between the knowing of the 5S method and the tendency to the 5S method.  H1= There is a significant difference between knowing of the 5S method and the tendency to the 5S method. |
| **14** | H0= There is no significant difference between whether there is a quality method applied or not, and the view that time and resource expenditures for quality improvement will reduce costs in the long run.  H1= There is a significant difference between whether there is a quality method applied or not, and the view that time and resource expenditures for quality improvement will reduce costs in the long run. |
| **15** | H0= There is no significant difference between the existence of the quality department and quality awareness.  H1= There is a significant difference between the existence of the quality department and quality awareness. |
| **16** | H0= There is no significant difference between the scale of the enterprise and quality awareness.  H1= There is a significant difference between the scale of the enterprise and the awareness of quality. |
| **17** | H0= There is no significant difference between the age of the enterprise and the quality awareness.  H1= There is a significant difference between the age of the enterprise and quality awareness. |
| **18** | H0= There is no significant difference between the existence of a quality department in the enterprise and the continuity of quality assurance.  H1= There is a significant difference between the existence of a quality department in the enterprise and the continuity of quality assurance. |
| **19** | H0= There is no significant difference between quality awareness and manager-employee cooperation.  H1= There is a significant difference between quality awareness and manager-employee cooperation. |

**4. FINDINGS**

A total of 19 non-parametric tests were performed on the answers to the different questions from the survey. With these tests, the following findings were obtained. It was important to make it clear that the tendency towards 5S is not related to either the age of the SME or its size. The results of hypothesis tests can be seen from Table-2. Another result has shown that the existence of a quality manager or quality department plays an essential role in ensuring that workers also receive the necessary quality training and education. It has been observed that as the size of the company increases, the applications of quality methods increase. It can be said that in companies with a high number of employees, the notion of quality has gained importance and quality practices have become the standard. In addition, no significant relationship was found between the errors caused by lack of information and informing the employees about the products, process, workflow, quality requirements, etc. This may be due to the inadequacy of the training provided or the lack of continuous control. As a result of the analysis, it was found that while employees received quality training, errors made by employees persisted. SMEs, most of which do not have qualified staff, should reconsider the quality and adequacy of the training provided.

Larger enterprises typically have more complex organizational structures, multiple departments, and diverse operations compared to smaller ones. Implementing 5S across a large organization requires significant coordination, resources, and time. There may be more resistance to change, bureaucratic hurdles, and challenges in standardizing processes across different locations or departments. In contrast, smaller enterprises may have fewer layers of management, making it easier to implement 5S practices with less bureaucracy and resistance (Greenwood et. al., 2011).

The variance in the adoption and effectiveness of 5S practices across different ages of enterprises and levels of quality awareness is influenced by several factors like: organizational culture and tradition, leadership and management style, investment in continuous improvement, resource availability(Akram et. al., 2023).

The lack of a staff structure to manage the training, the inability to identify managers' training needs, the workload of employees, the lack of time or the cost of the training can drastically affect the functionality of the training. Another result showed that infrastructure-related errors are observed regardless of the age of the respective SME. Lack of information about the field of activity, lack of qualified personnel in this field or problems with capital can lead to infrastructure-related errors. Another result is that the SMEs which have applied a quality method are highly based on the opinion that time and resource expenditures for quality improvement will reduce costs in the long run. Thus, there is an impression that the SMEs who also implemented a quality method use it consciously and also believe that it is helpful and leads to positive long-term effects.

**Table 2.** Non-parametric hypothesis test results

|  |  |  |
| --- | --- | --- |
| **Hypothesis Test number** | **P Value (α= 0,05)** | **Result** |
| 1. | P=0,133 | H0 = accepted |
| 2. | P=0,544 | H0 = accepted |
| 3. | P=0,020 | H0 = rejected |
| 4. | P=0,003 | H0 = rejected |
| 5. | P=0,661 | H0 =accepted |
| 6. | P=0,588 | H0 =accepted |
| 7. | P=0,010 | H0 =rejected |
| 8. | P=0,483 | H0 =accepted |
| 9. | P=0,669 | H0 =accepted |
| 10 | P=0,362 | H0 =accepted |
| 11. | P=0,463 | H0 =accepted |
| 12. | P=0,279 | H0 =accepted |
| 13. | P=0,029 | H0 =rejected |
| 14. | P=0,050 | H0 =rejected |
| 15. | P=0,009 | H0 = rejected |
| 16. | P=0,004 | H0 =rejected |
| 17. | P=0,905 | H0 =accepted |
| 18. | P=0,001 | H0 =rejected |
| 19. | P=0,001 | H0 =rejected |

Moreover, the presence of a quality department or supervisor in SMEs shows that the SME has more information about quality. In terms of both quality awareness and continuity of quality assurance, they have gained an advantage over SMEs that do not have a quality department or supervisor. In addition, micro and small SMEs are more quality conscious than medium-sized SMEs. This shows that it is easier to spread quality awareness in businesses with few employees. However, the age of SME did not affect quality awareness. This shows that newly formed SMEs do not have a relationship in terms of quality awareness compared to SMEs that have been operating for many years.

The challenges can be faced in this process stated below.

* **Resistance to Change**: Employees may resist adopting new processes and procedures associated with 5S due to fear of the unknown, concerns about job security, or reluctance to change established routines (Furxhi, 2021).
* **Lack of Management Support:** Without strong support and leadership from management, 5S initiatives may struggle to gain traction or sustain momentum. Management buy-in is crucial for allocating resources, providing guidance, and setting priorities (Albashar, 2024).
* **Insufficient Training and Education:** Inadequate training on 5S principles and techniques can hinder successful implementation. Employees need to understand the purpose and benefits of 5S, as well as how to effectively apply its principles in their work areas (Attri et. al. 2017).
* **Resource Constraints:** Limited financial resources, time, or personnel can impede 5S implementation efforts. Without sufficient resources, organizations may struggle to invest in necessary equipment, materials, or training programs (Lan Chi, 2024).
* **Sustainability Challenges:** Maintaining the gains achieved through 5S over the long term can be challenging. Without ongoing commitment and reinforcement, there is a risk of backsliding or regression to previous work habits and standards (Mihelcic et. al. 2017).
* **Cultural Barriers**: Organizational culture plays a significant role in the success of 5S initiatives. Cultural barriers such as lack of trust, resistance to collaboration, or a focus on short-term results over long-term improvement (Al Alawi et. al. 2007).
* **Measurement and Feedback:** Without clear metrics and feedback mechanisms in place, it can be difficult to assess the effectiveness of 5S implementation efforts and identify areas for improvement (Sati & Adam, 2019).

It is seen that SMEs with quality awareness are ahead in terms of manager-employee cooperation. Quality awareness emphasizes the cooperation between the manager and the employee. The evaluation of the hypothesis tests were made with the SPSS software. Two types of tests were used. One of the Mann Whitney U test and the Kruskal Wallis H test.

**5. CONCLUSION**

We live in a world where globalization determines our everyday life. As a result, however, the competition in the market is increasing every day, so companies need a significant difference in order to be able to stay on the market at all. Turkey, where 99.8% of all companies are SMEs, needs to take advantage of this fact as soon as possible in order to stand out and become more present in the international market. Quality is also an important factor that makes companies more efficient in the long term and gives them a competitive advantage. However, the research, especially in the literature, showed that Turkey is very passive when it comes to quality. There were large gaps in literature, especially when it came to quality awareness. Many manufacturing SMEs in Turkey have a lot of underqualified staff, which also drastically disadvantages production in terms of quality. Likewise, it has also been discovered that complicated quality methods such as Total Quality Management or Six Sigma would be too challenging for these types of SMEs and would not lead to long-term effectiveness. Thus, the main topic of this thesis is to make the 5S method better known and applicable to any SME. The 5S method is the easiest quality method to implement, which is uncomplicated, cost-effective and timesaving, while offering advantages such as reducing search and waiting times, short distances between individual stations and storage locations and sensible utilization of capacities, but also order and clarity helps to prevent accidents at work and increases the overall safety. Thus, the simple 5 steps of the 5S method, Sort, Set in Order, Shine, Standardize and Sustain, can change many things for the better and contribute a very high positive impact on the economy overall. However, the problems of the SMEs in terms of quality are very high at the moment.

The precautions that can be taken has been stated below:

* **Continuous Improvement:** Emphasize the significance of ongoing enhancement throughout the journey of 5S. Promote regular assessments, feedback mechanisms, and adjustments to address emerging obstacles and enhance outcomes continually(Furxhi, 2021).
* **Identify Specific Challenges:** Recognize the exact hurdles encountered during the implementation of 5S, such as employee resistance, lack of support from management, inadequate resources, or challenges in maintaining changes over time (Albashar, 2024).
* **Employee Training and Involvement:** Offer thorough training to employees regarding the principles and advantages of 5S. Encourage their active engagement in the process, as their participation is pivotal for successful execution (Attri et. al. 2017).
* **Management Support:** Ensure robust backing from senior management by showcasing the potential benefits of 5S, allocating required resources, and actively engaging in the implementation process (Al Alawi et. al. 2007).
* **Establish Clear Goals and Standards:** Define precise objectives and benchmarks for each phase of the 5S process. This offers clarity and guidance, steering efforts towards achieving tangible results (Mihelcic et. al. 2017).
* **Address Resistance and Cultural Change:** Tackle resistance to change by fostering a culture of transparency, communication, and collaboration. Encourage feedback and handle concerns constructively to garner support from all stakeholders (Al Alawi et. al. 2007).
* **Celebrate Successes and Learn from Failures:** Acknowledge and commemorate accomplishments and milestones attained during implementation of 5S. Similarly, perceive setbacks and failures as opportunities for learning, refining strategies, and enhancing future endeavors (Sati & Adam, 2019).
* **Ensure Sustainability:** Implement strategies to uphold the benefits achieved through 5S by integrating its principles into daily practices, establishing routines for upkeep and enhancement, and nurturing a culture of ownership and responsibility (Mihelcic et. al. 2017).

In order to go into these quality problems in more detail, a survey was conducted with the manufacturing SMEs in Ankara. The aim was to better understand the SMEs, to measure their quality awareness and also to see the status of the quality. During the survey alone, it was quite difficult to get the answers, many SMEs were unwilling to fill out the survey or didn't even want to talk and distanced themselves. Finally, 50 SMEs took part in the survey and this number was enough to conduct non-parametric hypothesis tests. The test results were very different. With these results, one can make it clear that the tendency towards 5S does not play a role either with the age or with the size of the SME and that the 5S method can actually be implemented for all SMEs. It has been observed that as the size of the company increases, the applications of quality methods increase. One can say that in companies with a large number of employees, the idea of quality has gained importance. So, it can also be said that the basis for quality is already there for most of them, and only the performance needs to be increased. It is important to clarify that in the survey, 80% of the SMEs stated that the shortcomings and defects are caused by the employees. This is a very important clue. In general, one can also say that the quality of the quality training is not sufficient. This is where quality managers come into play. The quality managers bear a great deal of responsibility in training their employees sufficiently and increasing their quality awareness. This is exactly where the 5S method explained in this paper comes in. The 5S method in the full program could bring structure, order, certainty, awareness and also control, which is sorely lacking in the SMEs in Ankara. With 5S training, audits, checklists, and all other methods explained in this paper, the SMEs could make great progress in a short time to lead Turkey with all its SMEs to a high-quality manufacturing environment.

For future research directions, a larger-scale study may be conducted to confirm the current findings. Different type of studies implementing 5S also explore the effectiveness of various strategies in Turkish SMEs and support the idea of this article. Not only with 5S, but also various types of lean production methodologies such SOCT, Lean balancing, Kaizen can be investigated that what is the situation for specific areas or in Turkey.

**CONFLICT OF INTEREST**

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this paper.

**REFERENCES**

Ab Rahman, M. N., Khamis, N. K., Zain, R. M., Deros, B. M., & Mahmood, W. H. W. (2010). Implementation of 5S practices in the manufacturing companies: A case study. *American Journal of Applied Sciences*, *7*(8), 1182-1189.

Al‐Alawi, A. I., Al‐Marzooqi, N. Y., & Mohammed, Y. F. (2007). Organizational culture and knowledge sharing: critical success factors. *Journal of knowledge management*, *11*(2), 22-42.

Al Bashar, M., Taher, M. A., & Ashrafi, D. (2024). OVERCOMING LEAN TRANSFORMATION HURDLES IMPLEMENTING EFFICIENCY IN THE US MANUFACTURING INDUSTRY.

Ahire, A. A., Chaudhari, A. B., Ahirrao, O. S., & Sarode, V. B. (2021). Increasing Productivity Through Implementation of 5S Methodology In A Manufacturing Industry: A Case Study. *Int. J. Sci. Res. in Multidisciplinary Studies Vol*, *7*(7).

Agrahari, R. S., Dangle, P. A., & Chandratre, K. V. (2015). Implementation of 5S methodology in the small scale industry: a case study. *International Journal of Scientific & Technology Research*, *4*(4), 180-187.

Akram, M. W., Abbas, A., Khan, I. A., & Ahmad, M. F. (2023). The impact of effective implementation of the 5S concept on company performance: A Case Study of a Manufacturing Company. *NICE Research Journal*, *16*(2), 119-140.

Attri, R., Singh, B., & Mehra, S. (2017). Analysis of interaction among the barriers to 5S implementation using interpretive structural modeling approach. *Benchmarking: An International Journal*, *24*(7), 1834-1853.

Chi, Do. (2024). Improving Economic Efficiency and Occupational Safety in Production Facilities Using the 5S-Kaizen Method. Sustainability in Environment. 9. p44. 10.22158/se.v9n1p44.

Ezzeddine R, Aoun M. (2020). The effect of 5S on Employee Performance: An Empirical Study among Lebanese Hospitals. *Int Bus Account Res J*; 4:44.

Furxhi, G. (2021). Employee’s resistance and organizational change factors. *European Journal of Business and Management Research*, *6*(2), 30-32.

Gala, B., & Wolniak, R. (2013). Problems of implementation 5S practices in an industrial company. *Management Systems in Production Engineering*.

Greenwood, R., Raynard, M., Kodeih, F., Micelotta, E. R., & Lounsbury, M. (2011). Institutional complexity and organizational responses. *Academy of Management annals*, *5*(1), 317-371

Mihelcic, J. R., Naughton, C. C., Verbyla, M. E., Zhang, Q., Schweitzer, R. W., Oakley, S. M., ... & Whiteford, L. M. (2017). The grandest challenge of all: The role of environmental engineering to achieve sustainability in the world's developing regions. *Environmental Engineering Science*, *34*(1), 16-41.

Mishra, R. P., & Chakraborty, A. (2014). Strengths, weaknesses, opportunities and threats analysis of lean implementation frameworks. *International Journal of Lean Enterprise Research*, *1*(2), 162-182.

Nilipour, A., & Jamshidian, M. (2005). 5S as an environmental organization management tool: benefits and barriers. In *Proceedings of the 3rd international management conference*.

Purohit, S. R., & Shantha, V. (2015). Implementation of 5S methodology in a manufacturing industry. *International Journal of Scientific & Engineering Research*, *6*(8), 225-231.

Radzali, M. A., & Thomas, V. (2020). Assessment on 5S approach strategy for small medium enterprise (SME): a case study in Sabah. *Journal of advanced mechanical engineering applications*, *1*(2), 7-19.

Ramdass, K. (2015, August). Integrating 5S principles with process improvement: A case study. In *2015 Portland International Conference on Management of Engineering and Technology (PICMET)* (pp. 1908-1917). IEEE.

Sánchez, P. M., Rodriguez, C. M., Maruyama, U., & Salazar, F. (2015, September). Impact of 5S on quality, productivity and organizational climate-Two Analysis Cases. In *Proceedings of the International Conference on Operations Excellence and Service Engineering* (pp. 748-755).

Sati, S. A., & Adam, A. I. (2019). Evaluating the effectiveness of 5S implementation in the industrial sector. *International journal of innovative science and research technology*, *4*(10), 804-808.

Sangode, P. B. (2018). Impact of 5s methodology on the efficiency of the workplace: study of manufacturing firms. *International Journal of Research in Commerce & Management*, *9*(12).

Shaikh, S., Alam, A. N., Ahmed, K. N., Sawant, I., & Hasan, S. Z. (2015). Implementation of 5S practices in a small-scale organization: a case study. *International Journal of Engineering and Management Research (IJEMR)*, *5*(2), 130-135.

Titu, M. A., Oprean, C., & Grecu, D. (2010, March). Applying the Kaizen method and the 5S technique in the activity of post-sale services in the knowledge-based organization. In *Proceedings of the International Multiconference of engineers and computer scientists* (Vol. 3, No. 1, pp. 1-5).

Türkiye İstatistik Kurumu (TÜİK), “KOBİ İstatistikleri Raporu (2009-2019)”, 2020.

Van Patten, J. (2006). A second look at 5S. *Quality progress*, *39*(10), 55.

Zadry, H. R., & Darwin, R. (2020, December). The Success of 5S and PDCA Implementation in Increasing the Productivity of an SME in West Sumatra. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1003, No. 1, p. 012075). IOP Publishing.

**Evaluation of Digital Health Services From a Legal Perspective**

Servet Soygüder1\*, Murat Kızılırmak2

1Ankara Yıldırım Beyazıt University

ORCID No: <http://orcid.org/>0000-0002-8191-6891

2Ankara Yıldırım Beyazıt University,

ORCID No: <http://orcid.org/>0009-0008-2359-1866

|  |  |
| --- | --- |
| **Anahtar Kelimeler** | **Öz** |
| *Sağlık,*  *Dijital Sağlık,*  *Dijital*  *Sağlık Uygulamaları,*  *Hukuki Altyapı,* | *Günümüzde sağlık sektörü, teknolojik ilerlemelerle birlikte dijitalleşme sürecine hızla adapte olmaktadır. Bu dijital dönüşüm, sağlık hizmetlerini iyileştirmeyi ve etkinleştirmeyi amaçlayan birçok avantajı beraberinde getirirken, aynı zamanda ciddi hukuki zorlukları da beraberinde getirmektedir. Bu makale, dijital sağlık ve hukuk arasındaki kritik ilişkiyi ele alarak, dünya genelinde sağlık sektörünün dijitalleşme sürecini incelemeyi amaçlamaktadır. Aynı zamanda dünya çapında aktif olarak kullanılan dijital sağlık uygulamalarının hem web hem de mobil platformları kapsamlı bir şekilde incelenmiş ve irdelenmiştir. Yapılan araştırmalarda; bu uygulamaların temel işlevselliği, randevu sistemleri, ödeme sistemleri ve özellikle hukuki alt yapıları ele alınmıştır. Bu çalışmada dijital sağlık uygulamalarının sunduğu hizmetlerin detaylı analizini, kullanıcı deneyimlerini, veri güvenliğini ve hukuki uyumluluk açılarını kapsamlı bir bakış açısı sunmayı amaçlamaktadır. Dijital sağlık alanında faaliyet gösteren özel ve devlet kurumlarının ve sağlık profesyonellerinin, bu karmaşık düzenlemelere uyum sağlamak için benimsemeleri gereken en iyi uygulamaları anlamak, makalenin temel hedeflerindendir.* |

**Evaluation of Digital Health Services From a Legal Perspective**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Keywords** | | **Abstract** | | |
| *Health,*  *Digital Health,*  *Digital Health Applications, Legal Framework* | | *In today's world, the healthcare sector is rapidly adapting to the process of digitization with technological advancements. While this digital transformation brings numerous advantages aimed at improving and streamlining healthcare services, it also presents significant legal challenges. This article aims to examine the critical relationship between digital health and law, intending to explore the global digitization process in the healthcare sector. Additionally, it comprehensively investigates both web and mobile platforms of digital health applications actively used worldwide. In the conducted research, the fundamental functionality of these applications, appointment systems, payment systems, and especially their legal frameworks are addressed. This study aims to provide a comprehensive perspective on the detailed analysis of the services offered by digital health applications, user experiences, data security, and legal compliance aspects. Understanding the best practices that private and public institutions and healthcare professionals operating in the digital health field need to adopt to comply with these complex regulations is a fundamental goal of the article.* | | |
| Araştırma Makalesi |  | | Research Article |  |
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1. **INTRODUCTION**

Developments in technology and decreasing costs have increased individuals' access to technological tools and applications. This easy access to technology has enabled people to carry out their activities in the digital environment with computers, smart mobile phones, tablets, and other systems and tools that help access necessary services without being physically present (Demirci, Ş. 2018). Digital technologies affect many issues such as the way people live, what they do in their spare time, how they work, their relationships with other people and the way they think.

[[4]](#footnote-4)

Digital technologies, which affect many sectors in addition to their impact on humans, have a profound impact, especially on the healthcare sector (Dorn, 2015). Digital health technologies are defined as systems and tools that enable individuals to control their own health status, comply with treatment protocols, encourage preventive health activities, and strengthen communication between the individual and the healthcare professional. These technologies include applications such as the internet, mobile technologies, social networks, and e-mail. Digital health differs slightly from traditional healthcare settings and focuses on data management, mobile technologies and communication tools rather than complex equipment. These technologies include genetic mapping, digital medical imaging devices and various digital health applications aimed at improving human health. Digital technologies aim to create an integrated healthcare system between patients, healthcare professionals, stakeholders and companies by redefining the boundaries in the healthcare system. However, in this digitalization process, the role played by law is often overlooked. Digital transformation in the healthcare sector brings with it a number of complex legal issues such as data security, patient privacy, medical device regulations and telemedicine. Digital health law is constantly evolving to respond effectively and fairly to the challenges posed by technological advances in the healthcare industry. It has been determined in the literature that many studies have been carried out in this field. The article prepared by Özen aims to examine the impact and contributions of telemedicine and mobile health services, which are among the digital health applications and are becoming increasingly widespread in Turkey, to the United Nations' Sustainable Development Goals (Ozen, 2021). In their study, Yorulmaz, Odacı and Akkan emphasized the prevalence and importance of the e-pulse system in health services and aimed to determine the importance and usage of the e-pulse system in health services in Turkey by examining the awareness levels and e-pulse usage of citizens in Konya. (Yorulmaz, Odacı & Akkan, 2018). In his study, Toygar talked about the historical background and developments of E-health applications. (Toygar, 2018). In their studies, Avaner and Fedai focus on health information systems implemented in Turkey. Particularly, the duo touched upon the importance of digitalization in healthcare in terms of decision support processes. (Avaner & Fedai, 2018). In their work, Şimşir and Mete discuss the role of innovative digital technologies in medicine and what these technologies are to improve the quality of treatment. (Simsir & Mete, 2021). In their study, Akalın and Veranyurt emphasize the various advantages and disadvantages of artificial intelligence applications in the healthcare sector. The study also recommends that necessary legal regulations be made in the use of artificial intelligence applications. (Akalın & Veranyurt, 2021). In their studies, Uysal and Ulusinan examine the impact of concepts such as mobile health, artificial intelligence, digital hospital, which are included in the concept of e-health, on healthcare services and provide examples. (Uysal & Ulusinan, 2020). In his study, Küzeci evaluated the legal problems arising from the innovations brought by e-health applications. (KUzeci, 2018).

They discuss certain key legal structures that digital health companies and investors should consider and emerging legal trends affecting digital health practices in the United States (“US”), the European Union (“EU”), and the United Kingdom. (ICLG, 2023). In their study, Karaca, Özsal and Duru examined the factors in the adoption of health care services offered using telehealth applications by healthcare personnel. (Karaca, Özsal & Duru, 2022).

Due to Covid-19, US President Donald Trump mentioned in his announcement on March 17, 2020 that he would expand telehealth services for patients with online applications to promote social distance. (Global News, 2020). While Mengi talks about making the internal control structures in health systems more reliable in his study, he also mentions that biometric systems should be switched to this system because they are more reliable than other systems. (Mengi, 2013). In their studies, Aladağ, Kurtarangil, and Bahtiyar talked about authentication methods that can be used to protect confidentiality due to security vulnerabilities in information systems. (Aladag, Kurta-Rangil & Bahtiyar, 2014). Tuckson, Edmunds and Hodgkins explained telehealth comprehensively in their studies. In their study, they talk about nine basic aspects of service delivery and also make suggestions as a result of implications for future research. (Tuckson, Edmunds & Hodgkins, 2017). Finally; In his study, Doğramacı talks about the meanings of the term telemedicine in different countries. While talking about the development of the concept of telemedicine in accordance with its chronological order in the world, he examined the history of telemedicine in Turkey separately. In addition, while talking about the areas where telemedicine is applied and the benefits it brings, he also examined its legal infrastructure. (Doğramacı, 2020).

1. **DIGITAL HEALTH LAW**

Digital health includes many areas such as the provision of health services, management of personal data and the use of health technologies. In parallel with the advancement of digital health technology, digital health law has also developed. Digital health law is a special field of law that emerged with the technological developments in the health sector and the spread of digital health applications. Digital health faces different legal challenges. The first of the most important issues is the privacy and security of personal data. The use, sharing and storage of digital health data created electronically should be well managed from a legal perspective. Another important legal issue is the consideration of digital health applications such as telemedicine. Telemedicine is a method that enables patients to receive services remotely from healthcare professionals, and this brings about legal regulations to determine the boundaries and legal standards of medical practices. Digital health law; It incorporates many regulations and standards such as medical device security, patient rights, data security standards, and aims to create a reliable framework in the sector by determining the compliance and responsibilities of healthcare providers and digital health technology providers.

Keeping up with rapidly developing technology and updating the legal framework of these new technologies is a process that requires constantly staying up to date. Towards the end of the 1960s, with the introduction of computer technology into the health sector, digital health law began to lay its foundations. During this period, computers began to be used in administrative tasks such as hospital management and financial transactions. However, in these early applications, legal regulations were generally inadequate and specific legal standards regarding digital health had not yet been established. The 1980s and 1990s were a period when digital health law began to take shape. During this period, Electronic Health Records (EHR) and other information systems began to become widespread. The healthcare industry has begun to take steps to create regulatory frameworks on issues such as hospital information systems and patient information security. In the 2000s, the rapid development of the internet and mobile technologies made digital health law even more important. Sharing personal health information in electronic environments has created the need to protect the privacy of patients and determine the responsibilities of healthcare providers. During this period, legal regulations for digitalization in the healthcare sector began to increase around the world. Regulations in the field of law aim to ensure that both healthcare professionals and patients feel safe in the digital health environment. Digital health law in Turkey includes practices and legal orders regulating the use of technology, data security, and patient rights. Some important digital health law regulations in Turkey are as follows;

**Electronic Health Services:** Here, electronic health records, digital storage of patient data, digital prescription applications, etc. Includes topics.

**Access to Information:** Includes the right to obtain information regarding access to and sharing of health data.

**Processing and Privacy of Personal Health Data:** It determines the rules regarding the processing, storage and sharing of personal health data. Protection of personal data is important.

**Electronic Signature:** Includes the importance of electronic signature to ensure authentication and security in digital health services.

**Collection of Personal Data:** It includes obtaining the necessary information to ensure correct service delivery.

1. **COLLECTED PERSONAL DATA AND COLLECTION METHODS**

Personal data can be collected from the service application in various ways. Personal data is not collected unless voluntarily provided directly by the customer or through authorized representatives.

If the personal data collected needs to be divided into 2 stages, it may be in the table below;

* 1. **How is Personal Information Collected?**
* If a comment is published,
* Automatically (such as from cookies) when you visit sites or use services
* Such as when you participate in telehealth services and/or interact with in-app messaging services.
* From third parties (when payment is made using the payment processor)
* Can be collected by the customer verbally or through applications and forms.
* Identity information, e-mail address, financial information and relevant information required to complete the health record in order to benefit from its services.
* Create and maintain a record of care and services received. This may include electronic medical records, if available, audio and/or video files of consultations, and test results.
* From programs such as Microsoft HealthVault or Google Health,
* Information provided from smart devices,
* Location from GPS-enabled devices,
* Automatically over time and from our own and third-party websites, through tracking technologies such as cookies,
* The Websites may use Google Analytics to collect and store information about you.
  1. **Cookies**

Cookies are small pieces of information created when you visit a website. These are used to collect and store certain information about your interactions with the website, which we can later use to make your journey better. We can remove cookies from our computer at any time, and we also have the opportunity to choose to disable cookies from the settings of our internet browser.

**Session cookies** are temporary cookies that exist only for the duration of using the Website. Session cookies help the Website remember what was selected on the previous page, eliminating the need to re-enter information.

**Persistent cookies** are a type of cookies that are saved on the device after visiting the Website. For example, when you log in to the GPS System, a permanent cookie is created to remember the preferences so that the system remembers the selection the next time you log in.

**Advertising Cookies:** Used to personalize advertisements. They share information by remembering the sites you visit.

**Performance Cookies:** These cookies help understand site access, browsing habits and usage. This data does not contain personal information that could reveal individual identity.

1. **USE AND PURPOSE OF PERSONAL INFORMATION**

Uses personal information for service delivery, personalization, security and legal requirements.

* 1. **Offering Our Services**
* To manage your account, provide and personalize our services and process payments
* Providing customer support
* Providing information about services to the customer
  1. **Personalizing Your Experience**
* To improve users' experiences, both in terms of content and ease of use
* To adjust ads to attract customer's attention
  1. **Marketing**

Where you have given your express consent, we may use your personal information to inform you about services, including products, promotional offers and events.

* 1. **Other Situations**
* Track and monitor user interaction
* Ensuring the security of services
* To fulfill legal obligations
* To detect, prevent or investigate security violations,
* Payment information to carry out insurance and credit card transactions,
* Authentication,
* Creating de-identified information (e.g. statistics, market research)
* To convey health information to the customer (himself),

1. **USE AND DISCLOSURE OF PERSONAL DATA**

They have the right to notify employers, insurers and healthcare providers regarding medical care requests. Unauthorized use is not possible except where required by law. Consent is obtained before personal data is collected and used without permission.

They may collect, use and disclose personal data without permission, based on the 'legitimate interests' exception under the KVKK, in order to detect and prevent fraud and misuse of services. In such cases, relevant explanations will be made to the insurer or employer (DoctorAnywhere, ).

* 1. **Sharing Your Personal Information**

Personal Information is not licensed or disclosed to unaffiliated third parties except in cases of sale, legal requirements, transfer or merger of the company.

We may share Personal Information with third parties, including service providers, in certain situations or for certain purposes, including:

* It must be shared with general practitioners and medical team in order to provide the service.
* The e-mail, date of birth and contact information provided during website registration can be shared with professional consultants such as analysis advertising services and law firms.
* Personal Information may be shared with third parties upon request.
* May share personal information with affiliates in the corporate group.
* May share to comply with laws or obligations under these laws.
* Personal Information may be shared in connection with an asset sale, merger, bankruptcy or other business transaction.
* For advertising (as described in the cookies section)
* Additionally, de-identified information may be disclosed in order to perform analysis activities.
* With police, fire, ambulance and rescue services
* Public health institutions responsible for controlling infectious diseases,
* In processes within the scope of insurance
* If services are received through the ministry, information can also be shared with other institutions under the responsibility of the ministry.
* Applications that provide prescription services can be shared with pharmacies.
  1. **Purposes of Use of Shared Data**
* Sharing requested information with the Ministry of Health and other public institutions and organizations,
* Fulfilling legal requirements,
* Sharing the requested information with private insurance companies within the scope of eligibility inquiry,
* Information about the appointment,
* Planning and managing the operation of the institution,
* In order to improve health services,
* Invoicing for our services,
* Confirming the relationship with contracted institutions,
* Answering questions and complaints regarding health services,
* Taking precautions within the scope of data security,
* Providing campaign information
* Measuring patient satisfaction,

1. **The Storage of Personal Data**

Personal information is generally stored on the secure servers of the applications. Information is stored for a certain period of time depending on the application's regulations. This period is determined by each application's own regulation. In general, data stored indefinitely in case of legal necessity is deleted automatically or upon customer request if it no longer serves its purpose.

1. **Security Method and Data Protection**

Each country has its own Personal Data Protection Law. To ensure the security of Personal Information, precautions are taken against accidental, illegal or unauthorized access. However, they do not fully guarantee the security of information transmitted over the internet, and the responsibility of keeping the password transmitted to the customer confidential is left entirely to the customer.

In addition, some applications in the world, such as the Neyim Var application used in Turkey, have security measures taken by the Ministry of Health of the relevant countries. Although the same methods are not applied in every application, if we talk about general precautions against duplication of disclosure;

**Table 1.** Security methods

|  |  |
| --- | --- |
| Use of Firewalls, Anti-Virus Software and Data Loss Prevention | Virus Software and Data Loss Prevention |
| Network Security and Application Security Risks have been identified and precautions have been taken. | Risks have been identified and precautions have been taken. |
| Key Management Application Service providers are regularly audited. | Service providers are regularly audited. |
| Closed System Network Usage Personal data is reduced as much as possible. | Personal data is reduced as much as possible. |
| Information Technologies System Security Secure software development procedures are implemented. | Secure software development procedures are implemented. |
| Keeping Log Records Physical environments are secured against external risks. | Physical environments are secured against external risks. |
| Cloud Security The security of environments containing personal data is ensured. | The security of environments containing personal data is ensured. |
| Data Masking Regular training and awareness activities are carried out for employees. | Data Masking Regular training and awareness activities are carried out for employees. Regular training and awareness activities are carried out for employees. |
| Secure Transmission of Special Data. Commitments are made to ensure the confidentiality of the data. | Commitments are made to ensure the confidentiality of the data. |
| Intrusion Detection and Prevention Systems Secure Encryption/Use of Cryptographic Keys (SSL Technology) | Use of Secure Encryption/Cryptographic Keys (SSL Technology) |
| Cyber Security Measures Encrypted Backup | Encrypted Backup |
| Portable Media Encryption Account requires two-step authentication. | The account requires two-step authentication. |
| Keeping Access Logs |  |

1. **ACCURACY OF PERSONAL INFORMATION**

Since it is not possible to verify the information provided by customers who register on the site, application owners rely on the customer by taking the information provided by the customer as a reference. Some applications pull data from the Ministry of Health application used by countries. However, these applications generally assign responsibilities for data accuracy to the institutions and organizations that send data, healthcare personnel who enter data, people who add their own data to the system, and drug information service providers.

1. **CORRECTION OF PERSONAL DATA**

Generally, requests for correction of personal data are made in writing or via e-mail to the Data Protection Officers in the applications. Although this request varies on each site, the application determines an average response time of 2 weeks. This request may be paid or free of charge, depending on the application from which the service is received.

1. **CHİLDREN'S PERSONAL INFORMATION AND SERVICES**

In general, services are not provided to children under the age of 13. In some applications, this age goes up to 17. However, services may be provided at the discretion of the HCP (Health Care Professional).

If the child receiving the service is under the age of 18, he/she must have the permission of his/her parent or legal heir to benefit from the service.

Legal infrastructure such as the information received from individuals who have reached the age of majority, its use and sharing is valid for children as well.

1. **PRESCRIPTION**

The patient has a responsibility to ensure that their information is accurate and complete, and this means that the patient, knowingly or unknowingly, may influence the advice received and medications prescribed, which could lead to serious consequences. In this case, neither the system nor any doctor assumes responsibility. The patient can consult qualified doctors through online assessment surveys or secure video chat and then receive their treatments from pharmacies registered with the service. Doctors can provide documents such as prescriptions, referral letters, and notes whenever they see fit.

Due to the service of obtaining prescriptions from local pharmacies, patients have to choose e-health applications that serve in their own country, even if the applications serve in different countries.

1. **EXAMINATION AND APPOINTMENT**

Applications generally provide health services over the internet. As a result of the interviews, doctors state the patient's complaints and make the relevant diagnosis. Using e-health applications, especially in order to avoid wasting time, provides an advantage in this respect. Generally, these e-health services are not suitable for medical emergencies or any diagnosis or treatment that requires a physical examination.

Inspections are carried out by downloading the applications of the company to be serviced from the App Store for those who receive service from products with an iOS-based operating system, and from Google Play applications for those who receive service from products with an Android-based operating system. These services can be in the form of voice chat, video chat and messaging. At the same time, while some sites can receive service through their own sites, they also provide this service by using applications such as WhatsApp, Zoom, etc. One of the most important issues that should be taken into consideration here is that the services provided must be recorded or the legal infrastructure must be thoroughly learned. If you want to take legal action in the future in case of a misdiagnosis, your probability of being right without any evidence is almost zero. According to the information we received from WhatsApp, Audio and video calls on WhatsApp are end-to-end encrypted. Thus, whether you make calls from your phone or your computer, “WhatsApp cannot listen to or see these calls.” is an indication that we cannot claim rights.

1. **CONCLUSION AND DISCUSSION**

Data regarding the collection of personal data is conveyed above under the title "Collected Personal Data and Collection Methods". The conclusion to be drawn here is that data is collected by different methods and it is possible to partially block these methods. It is envisaged that this can be prevented by restricting the cookies section, but blocking or restricting personal information also restricts the service received. Because customer data is needed for the service.

The user cannot do much about sharing personal data; any security weakness means that the information will be used by a third person or institution. In today's age, especially services received over the internet, applications with weak cyber security measures cause data to be shared with a third party. Therefore, it brings with it the obligation to thoroughly research the data security policy of the application to be serviced and the methods applied for data protection. Although data is protected by law, it should not be forgotten that it can also be shared through illegal means. The accuracy of personal data is parallel to the accuracy of the service received. Therefore, users who will provide health services via the internet or mobile should add this data to the system carefully and accurately. As mentioned above, the information entered mostly holds the user responsible, not the application owner. Although it is possible to correct incorrectly entered information, this may cause loss of both time and money.

If the user accepts a service over the internet, he/she should especially read the terms of acceptance carefully. While some practices do not offer prescription services, some do. The most important part here is "Please note that Evital does not and will not give any medical advice through the Platform, does not aim to give medical advice, and does not provide guidance or recommendations regarding any diagnosis, prognosis or treatment", which I encountered while researching different applications (Evital, 2023). This article is an example of how careful we should be in this regard. Choosing companies that carry out the necessary procedures and provide approved digital health services in accordance with the regulations published in the official gazette in Turkey will increase the quality of the service received. By carelessly accepting this and similar articles before receiving service, while you think you are being treated, you are actually admitting that you are not legally receiving a service in exchange for money. The use of e-health applications has increased significantly today, especially due to expensive healthcare expenses in other countries. In addition to providing financial profit, these applications also provide significant benefits in terms of time. The examination, which will be carried out online, allows patients to receive service regardless of where or when they are.

**CONFLICT OF INTEREST**

The authors declared that there is no conflict of interest.

**REFERENCES**

Akalin, B., & Veranyurt, U. (2021). Saglik Hizmetleri ve Yonetiminde Yapay Zeka. Acta Infologica, 5(1), 231-240.

Aladag CE, Kurtarangil E, Bahtiyar S. (2014). Medikal bilgi sistemlerinde güvenlik, mahremiyet ve kimlik dogrulama. XVI. Akademik Bilisim Konferansı Bildirileri, 313-317.

Avaner, T., & Fedai, R. (2017). Saglik Hizmetlerinde Dijitallesme: Saglik Yönetiminde Bilgi Sistemlerinin Kullanilmasi. Suleyman Demirel universitesi Iktisadi Ve Idari Bilimler Fakultesi Dergisi, 22(Kayfor 15 Ozel Sayisi), 1533-1542.

Demirci, S. (2018). Sagligin Dijitallesmesi, Mehmet Akif Ersoy Universitesi Sosyal Bilimler Enstitusu Dergisi, 10, 710-721.

DoctorAnywhere “Gizlilik Ve Veri Koruma Politikası (“Gizlilik Politikası”)”. (2023). [DoctorAnywhere - Gizlilik Politikası](https://doctoranywhere.com/privacy-policy/)

Dogramacı YG. (2020). Teletip, Saglık Turizmi ve Uzaktan Saglik Hizmetleri: Mesafeli Sozlesmeler. İstanbul Hukuk Dergisi, 78(2), 657-710

Dorn, S. D. (2015). Digital Health: Hope, Hype, and Amara’s Law. Gastroenterology, 149(3), 516-520.

Evital “Evital - Danışan Odaklı E-Saglık Platformu Ve Web/Mobil Uygulamaları Platformu Kullanım Hukum Ve Kosulları”. (2023). ([Evital - Kullanıcı Hüküm ve Koşulları](https://evital.com.tr/kullanici/kullanim-hukum-ve-kosullari)

Global News, “A Division of Corus Entertaintment Inc. Coronavirus outbreak: Trump announces expansion of medicare telehealth services amid pandemic.”., [Global News](https://globalnews.ca/video/6689942/coronavirus-outbreak-trump-announces-expansionof-medicare-telehealth-services-amid-pandemic)

ICLG “Dijital Saglik Yasaları ve Duzenlemeleri Kuresel Dijital Saglik Duzenlemesinde Ortaya Cikan Egilimler 2023-2024”., [ICLG - Dijital Saglik Yasaları](https://iclg.com/practice-areas/digital-health-laws-and-regulations/05-emerging-trends-in-the-global-regulation-of-digital-health)

Karaca A, Orsal O, Duru P. (2022). Facilitators and barriers to healthcare professionals’ adoption of tele-health interventions. J Nursology. 25(3), 168-176.

Kuzeci, E. (2018). Saglik Bilisim Teknolojileri Ve Yeni Hukuksal Soru(N)Lar. Inonu Universitesi Hukuk Fakultesi Dergisi, 9(1), 477-506.

Mengi, B. T. (2013). Saglık Hizmetlerinde Meydana Gelebilecek Hileleri Onlemeye Yonelik Bir Uygulama Olarak Biyometrik Kimlik Dogrulama Sistemlerinin Kullanımı. Muhasebe Ve Finansman Dergisi, (60), 39-50.

Özen, H. (2021). Dunya Saglik Hizmetlerinin Surdurulebilir Kalkınma Hedefleri Acısından Degerlendirilmesi. OPUS–Uluslararası Toplum Arastırmaları Dergisi, 17(38), 5440-5472.

Simsir,I., Ve B. Mete, “The Future of Healthcare Services: Digital Health Technologies”, Journal of Innovative Healthcare Practices, c. 2, sy. 1, ss. 33–39, 2021.

Uysal, B., & Ulusinan, E. (2020). Guncel Dijital Saglik Uygulamalarının Incelenmesi. Selcuk Saglik Dergisi, 1(1), 46-60.

Toygar, Ş. A. (2018). E-Saglık uygulamalari. Yasama Dergisi (37), 101-123

Tuckson RV, Edmunds M, Hodgkins ML. (2017). Telehealth. N Engl J Med, 377(16),1585-1592.

Yorulmaz M & Odaci Ş. & Akkan M. (2018). Dijital Saglık Ve E-Nabiz Farkindalik Duzeyi Belirleme Calismasi. Selcuk Universitesi Sosyal ve Teknik Arastirmalar Dergisi, 16, 1-11

**A Review Of Mobile Health Application Rating Scales**

Melda Kevser Akgün1\*, Servet Soygüder2

1Ankara Yıldırım Beyazıt University,

ORCID No: <http://orcid.org/>0000-0001-7580-8352

2Ankara Yıldırım Beyazıt University,

ORCID No: <http://orcid.org/>0000-0002-8191-6891

|  |  |
| --- | --- |
| **Keywords** | **Abstract** |
| *e-health,*  *mobile health (mHealth),*  *health applications,*  *scale development,*  *app evaluation* | *Nowadays, mobile devices have evolved to solve almost every problem and have become an indispensable part of our daily lives. According to statistics, users spend an average of three to five hours on their smartphones each day, and approximately ninety percent of this time is spent on applications. As in other sectors, mobile health applications (mHealth apps.) are increasingly utilized. The high demand in this regard naturally causes the rapid proliferation of mHealth applications, and it is becoming more and more challenging for both patients and healthcare professionals to identify superior applications due to the vast selection available in stores, varying in quality, reliability, and adherence to best practices in healthcare. In this context, various surveys and frameworks such as MARS, uMARS, ORCHA-24, ENLIGHT, THESIS, and ACCU3RATE have been proposed to provide a systematic and standardized approach. In this study, a review of proposed rating scales will be conducted.* |
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**1. INTRODUCTION**

According to statistics, users spend an average of three to five hours per day on their smartphones, and this time increases every year (see Figure 1c). The widespread use of smartphones and mobile devices has contributed to the growing popularity of mobile applications (mobile apps) across various domains, including healthcare. The term "mHealth" (mobile health) emerged in the early 2000s.

[[5]](#footnote-5)Around the mid-2000s, the World Health Organization (WHO) recognized mHealth's potential and started using the term in its reports and initiatives, and by the 2010s, mHealth had become a well-established concept in the healthcare industry. WHO has defined mHealth as “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices” (Kay et al., 2011). mHealth encompasses a wide range of functionalities, such as health monitoring, remote consultations, health education and information, **medication adherence,** disease management, wellness and lifestyle management, and emergency response.

Mobile health applications (mHealth apps) are an integral part of the broader mHealth ecosystem, working in tandem with other mobile health technologies to advance the goals of improving healthcare access, delivery, and outcomes through mobile devices. mHealth apps may contribute to the democratization of healthcare, by improving access to services and empowering individuals to take control of their health and well-being. These apps serve various purposes within the realm of mHealth, including health monitoring, disease management, telemedicine consultations, medication reminders, fitness tracking, and health education. According to a study conducted in the USA in 2023, almost half of the participants stated that they use sleep and weight control applications. Additionally, one-fifth of the participants stated that they use medication management (MM) and mental health applications (see Figure 1a). Especially after the COVID-19 pandemic, people increasingly turned to digital solutions for managing their health and well-being in the face of pandemic-related challenges and restrictions, and this has accelerated the adoption of mHealth applications. The installation rate of mHealth applications has increased by 65 percent worldwide. In fact, according to statistics reports from Statista.com, in some countries, such as South Korea, a significant increase of 135 percent was observed.

A graph of a number of people

Description automatically generated with medium confidenceA pie chart with text

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Figure 1a Figure 1b

A bar chart of different countries/regions

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Figure 1c

**Figure 1.** Some statistics about digital health habits. (a) Adults' percentage in the U.S. who used an mHealth app. to monitor their health as of 2021. (b) Distribution of monthly frequency of utilization of mHealth apps in the U.S. in 2023. (c) Worldwide mHealth app. usage time from 2019 to 2022, per day, by country (in hours). (Source: Statista, 2024)

The high demand for digital healthcare solutions in this regard naturally causes the rapid proliferation of mHealth applications. Figure 2 shows the number of mHealth applications produced from 2015 to 2022 through the Apple App Store and Google Play Store. As can be seen, there’s been a noticeable rise in the number of mHealth applications since 2018, especially in the Play Store. Although having many alternatives seems to be an advantage, finding a high-quality mHealth app can be challenging due to the vast selection available in stores, varying in quality, reliability, and adherence to best practices in healthcare. Additionally, concerns regarding privacy, compatibility, and usability further complicate the process of selecting the most suitable mHealth app that offers accurate information, effective functionality, and robust security measures. Even though the number of downloads and star scores given by previous users are generally considered to evaluate application quality, studies show that the relationship is weak and insufficient (Azad-Khaneghah et al., 2021; Yamamoto et al., 2022). Moreover, star ratings and reviews in stores may be biased or deliberately written to mislead. In this context, various surveys and frameworks such as MARS, uMARS, ORCHA-24, ENLIGHT, THESIS, and ACCU3RATE have been proposed to provide a systematic and standardized approach to determining the quality of mHealth apps. In this study, a review of proposed rating scales will be conducted.

A graph showing the number of apps

Description automatically generatedA graph showing the number of apps in play store

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**Figure 2.** Number of available mHealth applications in the store (Source: Statista, 2024)

**2. SCALES FOR MOBILE HEALTH APP EVALUATION**

With the rapid proliferation of health-related apps, several scales and frameworks have been proposed to evaluate mHealth applications, aiming to provide a structured and systematic approach to assess their quality, usability, and effectiveness. Stoyanov et al. developed the Mobile Application Rating Scale (MARS) in 2015. The scale is used to systematically evaluate various aspects of mobile apps, including four objective qualities and one subjective quality based on user experience. Subsequently, Stoyanov and his colleagues simplified the language of the scale and proposed an end-user version of MARS known as u-MARS (Stoyanov et al., 2016). It has been developed as an extension of the original MARS framework and enables users to evaluate mobile apps from their perspective, considering factors that are important to their individual preferences and needs. In 2017, Leigh et al. proposed a specialized framework, namely ORCHA-24, focused specifically on evaluating the quality of health apps, with a particular emphasis on healthcare-related criteria and standards (Leigh et al., 2017). ORCHA-24 evaluates mHealth apps across 24 key domains, including usability, functionality, safety, and clinical effectiveness. Unlike MARS, ORCHA-24 is tailored specifically for the healthcare context. Baumel et al. proposed a new scale, ENLIGHT, which is specifically designed for digital mental health interventions, focusing on aspects such as content quality, therapeutic approach, and data security (Baumel et al., 2017). The scale evaluates various dimensions of digital mental health programs, including content quality, user engagement, therapeutic approach, usability, and data security. In 2021, Biswass et al. proposed a scale, namely ACCU3RATE, based on user reviews (Biswas et al., 2021). Like ENLIGHT, ACCU3RATE is intended exclusively to evaluate mHealth apps. Quite different from other studies, text mining by artificial intelligence was used for the first time on this scale.

Related scales, their main dimensions, and the validity tests performed are listed in Table 1. Of course, all these proposed scales have different advantages over each other. Nonetheless, among the proposed mHealth application evaluation scales, MARS is the most used one up to the present; therefore, the MARS scale will be analyzed in more detail in the continuation of the study.

**Table 1.** Dimensions and performance metrics for well-known rating scales

|  |  |  |
| --- | --- | --- |
| **Scale** | **Dimensions** | **Performance Metric** |
| MARS | Engagement, functionality, esthetics, information, quality | ICC |
| uMARS | Engagement, functionality, esthetics, information, quality | ICC |
| ORCHA-24 | Data governance, clinical efficacy and assurance, user experience and engagement | IR, ICC |
| ENLIGHT | Usability, visual design, user engagement, content, therapeutic persuasiveness, therapeutic alliance | ICC |
| THESIS | Usability, security/privacy, technical and health content, transparency | IR, ICC |
| ACCU3RATE | User star rating, user text review, UI design, functionality, security and privacy, clinical approval | ICC |

\*ICC: Intra-class Corelation Coefficient, IR: Interrater reliability

**3. MOBILE APPLICATION RATING SCALE (MARS)**

Stoyanov et al. proposed the MARS scale, which consists of five main clusters, including four objective dimensions such as engagement, functionality, aesthetics, and information quality, and one subjective dimension based on user experience. They created a survey, which consisted of 23 items in total. For each survey question, the reviewer used a 5-point scale (such as 1: inadequate, 2: poor, 3: acceptable, 4: good, 5: excellent). The average score of subscales has been accepted as the score of each dimension, and the average score of dimensions has been accepted as the overall score of the relevant application. The scale was first tested in mental health applications, then validity tests were completed in many areas, and good inter-rater reliability results were obtained (Stoyanov et al., 2015).

**3.1. Adapted Version of MARS And UMARS For Different Countries**

In recent years, the MARS scale has been adopted and translated into multiple languages, including Turkish. While the original English version of MARS provides a robust framework worldwide, its effectiveness is limited when evaluators and users are not proficient in English. Considering Turkey as an example, according to the English Proficiency Index (EPI), Turkey ranks 66th out of 113 countries in 2023, and its proficiency is categorized as low (EPI, 2023). Establishing a national-level framework will be effective in preventing reduced usage due to low English proficiency levels. In this context, many countries have chosen to adapt the scale to their national languages. Translating MARS into other languages enhances its efficiency, accessibility, and relevance, allowing non-English-speaking researchers, healthcare professionals, and app developers to utilize the tool effectively. Additionally, the translations help capture culturally specific nuances and preferences in app use and engagement, leading to more accurate and contextually relevant assessments. For example, in the Japanese adaptation, the authors stated that there is no Japanese word to express the concept of “engagement” (Yamamoto et al., 2022). Creating national versions of the MARS scale is important to prevent such language-related logical confusion. The expansion of MARS into multiple languages ensures that the evaluation of mHealth apps is consistent and reliable globally, addressing the diverse needs of users across various regions. Also, this ultimately contributes to the global standardization of mHealth app evaluations, promoting high-quality health interventions worldwide. In most of these studies, validity and reliability tests were also conducted for national applications, and high scores were obtained. Related studies are listed in Table 2.

**Table 2.** MARS and adaptations for different countries

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Year** | **Country** | **Reference** | **Year** | **Country** | **Reference** |
| 2015 | Original | Stoyanov et al., 2015 | 2022 | Japan | Yamamoto et al., 2022 |
| 2016 | Italy | Domnich et al., 2016 | 2022 | Persia | Barzegari et al., 2022 |
| 2019 | Spain | Payo et al., 2019 | 2022 | Korea | Hee Ko et al., 2022 |
| 2020 | Arabia | Bardus et al., 2020 | 2022 | Turkey | Mendi et al., 2022 |
| 2020 | Germany | Messner et al., 2020 |  |  |  |

Besides, like MARS, uMARS has been adapted to some countries, such as Australia (Stoyanov et al., 2016), Spanish (Ruben, et al.), Japan (Mendi et al., 2022), Greece (Shinohara et al., 2022), and Turkey (Calik et al., 2022).

**3.2. Applications of The MARS**

MARS framework has found widespread application to evaluate a diverse range of mHealth apps across various health conditions and diseases, providing a standardized framework. Studies have applied MARS to assess apps designed for mental health, such as those targeting depression, anxiety, and stress management, highlighting its effectiveness in evaluating therapeutic engagement and content quality in psychological interventions. Additionally, MARS has been used to evaluate apps for chronic disease management, ensuring that these apps provide reliable and user-friendly tools for monitoring and managing these conditions. Fitness and wellness apps, focusing on exercise, diet, and overall well-being, have also been evaluated using the MARS framework, underscoring its versatility in assessing a broad spectrum of health-related applications. Related studies are listed in Table 3.

**Table 3.** Healthcare fields where MARS is used in application quality assessment.

|  |  |  |  |
| --- | --- | --- | --- |
| **Content** | **Reference** | **Content** | **Reference** |
| Well-being apps | Stoyanov et al., 2015 | COVID19 | Davalbhakta et al., 2020 |
| Mindfullness | Mani et al., 2015 | Weight management | Bardus et al., 2020 |
| Heart failure | Creber et al., 2016 | Anxiety | Messner et al., 2020 |
| Back pain | Machado et al., 2016 | Chronic health conditions | Miro et al., 2021 |
| Weight management | Bardus et al., 2016 | COVID19 | Martin et al., 2021 |
| Rheumatoid Arthritis | Grainger et al., 2017 | Smartphone addiction | Barzegari et al., 2022 |
| Smoking cessation | Thornton et al., 2017 | Pregnancy tracking | Mendi et al., 2022 |
| Chronic pain | Salazar et al., 2018 | Lung transplant | Shinohara et al., 2022 |
| Health and fitness | Payo et al., 2019 | Mental health | Yamamoto et al., 2022 |
| Rheumatology | Knitza et al., 2019 | Abortion | Stifani et al., 2023 |
| Genitourinary tumors | Amor et al., 2020 |  |  |

**4. MHEALTH APPLICATION STUDIES IN TURKEY**

Studies evaluating mHealth apps in Turkey have been growing, reflecting the global trend of incorporating digital health tools into healthcare practices. Although the original MARS scale is globally applicable, all articles describing MARS and uMARS adaptations emphasize the need for cultural and language-specific mHealth app rating scales. Recently, Mendi et al. (2022) adapted MARS for Turkey and completed the validity tests, Calik et al. (2022) adapted uMARS for Turkey and completed the validity tests, aiming to ensure they meet the specific needs and preferences of Turkish users. Both studies show that national scales are reliable and valid. Additionally, MARS has been used to evaluate some mHealth applications such as mindfulness (Duman et al., 2022), digital parenting (Aydoğdu et al., 2023), and pregnancy tracking (Mendi et al., 2022). Furthermore, the MARS scale was employed by Uslu and Arıkan to assess the ESİM mobile application, which is intended for people with hearing impairments.

**5. CONCLUSION**

The increasing usage of smartphones and the exponential growth of mobile applications have revolutionized the healthcare landscape, and the term "mHealth" emerged. mHealth applications, designed to improve health outcomes and facilitate healthcare access, have become integral tools for all stakeholders in the healthcare system. In this situation, the quality of mHealth applications plays a pivotal role in ensuring their effectiveness, user satisfaction, and overall impact on healthcare delivery. Despite the Food and Drug Administration's efforts, there is no globally accepted standard yet. However, several surveys and frameworks, such as MARS, uMARS, ORCHA-24, ENLIGHT, THESIS, and ACCU3RATE, have been proposed in recent years. Proposed scales are essential tools in the rapidly evolving field of digital health for both healthcare providers and users. They help in identifying which apps are likely to be beneficial for users and which ones need improvement. Also, by setting high standards and providing transparent evaluations, they contribute significantly to the overall quality and credibility of mobile health technologies.

**CONFLICTS OF INTEREST**

The authors declared that there is no conflict of interest.

**CONTRIBUTION OF AUTHORS**

This study is based on Melda Kevser Akgün’s doctoral thesis. Prof. Dr. Servet Soygüder is the thesis supervisor.

**REFERENCES**

Amor-García, M. Á., Collado-Borrell, R., Escudero-Vilaplana, V., Melgarejo-Ortuño, A., Herranz-Alonso, A., Arija, J. Á. A., and Sanjurjo-Sáez, M. (2020). Assessing apps for patients with genitourinary tumors using the mobile application rating scale (MARS): systematic search in app stores and content analysis. JMIR mHealth and uHealth, 8(7):e17609. <https://doi.org/10.2196/17609>

Azad-Khaneghah, P., Neubauer, N., Miguel Cruz, A., and Liu, L. (2021). Mobile health app usability and quality rating scales: a systematic review. Disability and Rehabilitation: Assistive Technology, 16(7):712–721. <https://doi.org/10.1080/17483107.2019.1701103>

Aydoğdu, Y.Ö., Durak, H.Y., And Akgün, E. (2023). Investigating the validity and reliability of the mobile application rating scale. Bartın University Journal of Faculty of Education, 12(3):570–578. <https://doi.org/10.14686/buefad.1274394>

Bardus, M., Awada, N., Ghandour, L. A., Fares, E.-J., Gherbal, T., Al-Zanati, T., and Stoyanov, S. R. (2020). The Arabic version of the mobile app rating scale: development and validation study. JMIR mHealth and uHealth, 8(3):e16956. <https://doi.org/10.2196/16956>

Bardus, M., Van Beurden, S. B., Smith, J. R., and Abraham, C. (2016). A review and content analysis of engagement, functionality, aesthetics, information quality, and change techniques in the most popular commercial apps for weight management. International Journal of Behavioral Nutrition and Physical Activity, 13(1):1–9. <https://doi.org/10.1186/s12966-016-0359-9>

Barzegari, S., Sharifi Kia, A., Barzegari, M., Stoyanov, S. R., GhaziSaeedi, M., and Rafizadeh, M. (2022). The Persian version of the mobile application rating scale (MARS-fa): Translation and validation study. JMIR Formative Research, 6(12):e42225. <https://doi.org/10.2196/42225>

Baumel, A., Faber, K., Mathur, N., Kane, J. M., and Muench, F. (2017). Enlight: a comprehensive quality and therapeutic potential evaluation tool for mobile and web-based ehealth interventions. Journal of Medical Internet Research, 19(3):e82. <https://doi.org/10.2196/jmir.7270>

Biswas, M., Tania, M. H., Kaiser, M. S., Kabir, R., Mahmud, M., and Kemal, A. A. (2021). Accu3rate: A mobile health application rating scale based on user reviews. PLOS ONE, 16(12):e0258050. <https://doi.org/10.1371/journal.pone.0258050>

Calik, G., Kartal, B. B., Stoyanov, S., Gravas, S., Othman, L., de la Rosette, J., Albayrak, S., and Laguna, P. (2022). Turkish validation of the user version of the mobile application rating scale. Turkish Journal of Urology, 48(3):236–242. <https://doi.org/10.5152/tud.2022.21324>

Creber, R. M. M., Maurer, M. S., Reading, M., Hiraldo, G., Hickey, K. T., and Iribarren, S. (2016). Review and analysis of existing mobile phone apps to support heart failure symptom monitoring and self-care management using the mobile application rating scale (MARS). JMIR mHealth and uHealth, 4(2):e5882. <https://doi.org/10.2196/mhealth.5882>

Davalbhakta, S., Advani, S., Kumar, S., Agarwal, V., Bhoyar, S., Fedirko, E., Misra, D. P., Goel, A., Gupta, L., and Agarwal, V. (2020). A systematic review of smartphone applications available for corona virus disease 2019 (COVID-19) and the assessment of their quality using the mobile application rating scale (MARS). Journal of Medical Systems, 44:1–15. <https://doi.org/10.1007/s10916-020-01633-3>

Dilek, U., and Arikan, G. (2023). Engelsiz sağlık iletişim merkezi mobil uygulamasının sistem kullanılabilirlik değerlendirilmesi. Ankara Hacı Bayram Veli Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 25(2):567–588. <https://doi.org/10.30913/ahbvu.1190765>

Domnich, A., Arata, L., Amicizia, D., Signori, A., Patrick, B., Stoyanov, S., Hides, L., Gasparini, R., and Panatto, D. (2016). Development and validation of the Italian version of the mobile application rating scale and its generalizability to apps targeting primary prevention. BMC Medical Informatics and Decision Making, 16(1):1–10. <https://doi.org/10.1186/s12911-016-0373-0>

Duman, S., Tanrıklulu, G., and Demirel, B. (2022). Mindfulness mobile app user quality evaluation: MARS scale adaptation. 11th International Conference on Culture and Civilization (pp. 134–139). Mardin, Turkey.

EPI. (2023). EF EPI, The world’s largest ranking of countries and regions by English skills. Accessed: 2023-12-13.

Grainger, R., Townsley, H., White, B., Langlotz, T., Taylor, W. J., et al. (2017). Apps for people with rheumatoid arthritis to monitor their disease activity: a review of apps for best practice and quality. JMIR mHealth and uHealth, 5(2):e6956. <https://doi.org/10.2196/mhealth.6956>

Hee Ko, K. K., Kim, S. K., Lee, Y., Lee, J. Y., and Stoyanov, S. R. (2022). Validation of a Korean version of mobile app rating scale (MARS) for apps targeting disease management. Health Informatics Journal, 28(2):14604582221091975. <https://doi.org/10.1177/14604582221091975>

Kay, M., Santos, J., and Takane, M. (2011). mHealth: New horizons for health through mobile technologies. World Health Organization, 64(7):66–71.

Knitza, J., Tascilar, K., Messner, E.-M., Meyer, M., Vossen, D., Pulla, A., Bosch, P., Kittler, J., Kleyer, A., Sewerin, P., et al. (2019). German mobile apps in rheumatology: review and analysis using the mobile application rating scale (MARS). JMIR mHealth and uHealth, 7(8):e14991. <https://doi.org/10.2196/14991>

Korkmaz, S., and Arikan, G. (2021). e-nabız uygulamasını değerlendirmek için kullanılan yeni bir araç: Mobil uygulama derecelendirme ölçeği. Ankara Hacı Bayram Veli Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 23(3):625–636. <https://doi.org/10.30913/ahbvu.982160>

Leigh, S., Ouyang, J., and Mimnagh, C. (2017). Effective? Engaging? Secure? Applying the ORCHA-24 framework to evaluate apps for chronic insomnia disorder. BMJ Ment Health, 20(4):e20–e20. <https://doi.org/10.1136/eb-2017-102767>

Levine, D. M., Co, Z., Newmark, L. P., Groisser, A. R., Holmgren, A. J., Haas, J. S., and Bates, D. W. (2020). Design and testing of a mobile health application rating tool. NPJ Digital Medicine, 3(1):74. <https://doi.org/10.1038/s41746-020-0276-0>

Machado, G. C., Pinheiro, M. B., Lee, H., Ahmed, O. H., Hendrick, P., Williams, C., and Kamper, S. J. (2016). Smartphone apps for the self-management of low back pain: a systematic review. Best Practice & Research Clinical Rheumatology, 30(6):1098–1109. <https://doi.org/10.1016/j.berh.2017.04.002>

Mani, M., Kavanagh, D. J., Hides, L., and Stoyanov, S. R., et al. (2015). Review and evaluation of mindfulness-based iPhone apps. JMIR mHealth and uHealth, 3(3):e4328. <https://doi.org/10.2196/mhealth.4328>

Martin-Payo, R., Carrasco-Santos, S., Cuesta, M., Stoyan, S., Gonzalez-Mendez, X., and Fernandez-Alvarez, M. d. M. (2021). Spanish adaptation and validation of the user version of the mobile application rating scale (uMARS). Journal of the American Medical Informatics Association, 28(12):2681–2686. <https://doi.org/10.1093/jamia/ocab201>

Mendi, O., Sari, M. K., Stoyanov, S., and Mendi, B. (2022). Development and validation of the Turkish version of the mobile app rating scale MARS-TR. International Journal of Medical Informatics, 166:104843. <https://doi.org/10.1016/j.ijmedinf.2022.104843>

Messner, E.-M., Terhorst, Y., Barke, A., Baumeister, H., Stoyanov, S., Hides, L., Kavanagh, D., Pryss, R., Sander, L., Probst, T., et al. (2020). The German version of the mobile app rating scale (MARS-G): development and validation study. JMIR mHealth and uHealth, 8(3):e14479. <https://doi.org/10.2196/14479>

Miro, J., Llorens-Vernet, P., et al. (2021). Assessing the quality of mobile health-related apps: interrater reliability study of two guides. JMIR mHealth and uHealth, 9(4):e26471. <https://doi.org/10.2196/26471>

Payo, R. M., Álvarez, M. F., Díaz, M. B., Izquierdo, M. C., Stoyanov, S. R., and Suárez, E. L. (2019). Spanish adaptation and validation of the mobile application rating scale questionnaire. International Journal of Medical Informatics, 129:95–99. <https://doi.org/10.1016/j.ijmedinf.2019.06.004>

Salazar, A., de Sola, H., Failde, I., Moral-Munoz, J. A., et al. (2018). Measuring the quality of mobile apps for the management of pain: systematic search and evaluation using the mobile app rating scale. JMIR mHealth and uHealth, 6(10):e10718. <https://doi.org/10.2196/10718>

Shinohara, Y., Yamamoto, K., Ito, M., Sakata, M., Koizumi, S., Hashisako, M., Sato, M., Wannous, M., Stoyanov, S. R., Nakajima, J., et al. (2022). Development and validation of the Japanese version of the uMARS (user version of the mobile app rating system). International Journal of Medical Informatics, 165:104809. <https://doi.org/10.1016/j.ijmedinf.2022.104809>

Statista. (2024). Number of hours spent per day using apps worldwide from 2019 to 2023, by country (in hours). Retrieved 10.02.24 from <https://www.statista.com/statistics/1269704/time-spent-mobile-apps-worldwide/>.

Statista. (2024). Number of mHealth apps available in the Apple App Store from 1st quarter 2015 to 3rd quarter 2022. Retrieved 10.02.24 from <https://www.statista.com/statistics/779910/health-apps-available-ios-worldwide/>.

Statista. (2024). Number of mHealth apps available in the Google Play Store from 1st quarter 2015 to 3rd quarter 2022. Retrieved 10.02.24 from <https://www.statista.com/statistics/779919/health-apps-available-google-play-worldwide/>.

Stifani, B. M., Peters, M., French, K., and Gill, R. K. (2023). There’s an app for it: A systematic review of mobile apps providing information about abortion using a revised MARS scale. PLOS Digital Health, 2(7):e0000277. <https://doi.org/10.1371/journal.pdig.0000277>

Stoyanov, S. R., Hides, L., Kavanagh, D. J., and Wilson, H. (2016). Development and validation of the user version of the mobile application rating scale (uMARS). JMIR mHealth and uHealth, 4(2):e5849. <https://doi.org/10.2196/mhealth.5849>

Stoyanov, S. R., Hides, L., Kavanagh, D. J., Zelenko, O., Tjondronegoro, D., and Mani, M. (2015). Mobile app rating scale: a new tool for assessing the quality of health mobile apps. JMIR mHealth and uHealth, 3(1):e3422. <https://doi.org/10.2196/mhealth.3422>

**Telehealth From A Patient Perspective**

Servet Soygüder1\* , Muhammed Onur Karamuk2

1Ankara Yıldırım Beyazıt University,

ORCID No: <http://orcid.org/>0000-0002-8191-6891

2Ankara Yıldırım Beyazıt University,

ORCID No: <http://orcid.org/0009-0000-7145-6572>

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| **Keywords** | **Abstract** |
| *Telemedicine,*  *Telehealth,*  *Digital health,*  *Patient satisfaction, Patient-centered care,* | *Telemedicine is a field of healthcare that involves the use of telecommunication technologies to provide remote medical care. By leveraging technologies such as videoconferencing, remote monitoring, and electronic messaging, healthcare providers can diagnose and treat patients in remote locations, without the need for in-person visits. Telemedicine has the potential to improve patient access to care, reduce healthcare costs, and improve health outcomes, especially for patients who live in rural or remote areas. In addition to the benefits outlined above, telemedicine has also been shown to improve patient satisfaction and reduce hospital readmission rates. Patients appreciate the convenience of being able to connect with their healthcare providers from their homes, without having to travel long distances or sit in crowded waiting rooms. Moreover, telemedicine can be especially beneficial for patients who have mobility limitations, live in rural areas, or are unable to leave their homes due to chronic illnesses. Overall, the rise of telemedicine is a positive development for patients, offering a range of benefits that can help improve their overall health and wellbeing. With the ongoing development of telemedicine technologies, the field is poised to play an increasingly important role in the delivery of healthcare services in the years to come. This study provides an overview of telemedicine and identifies its benefits and challenges. It also compares and analyzes the all-round performance of telemedicine technology compared to conventional medical services.* |
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**1. INTRODUCTION**

A telehealth system is a system where patients and doctors can access medical counseling and treatment services using digital technologies.

[[6]](#footnote-6)

Unlike traditional healthcare, telehealth enables patients to receive healthcare services via phone, video call or the internet, without the need to physically visit a doctor. In this way, patients can receive faster, more efficient and affordable healthcare services without being dependent on space and time. For the patient, a telehealth system is a system that provides convenience in accessing health services. This system enables patients to see their doctors from their homes, workplaces or anywhere else. Thus, patients can receive fast and efficient healthcare services without facing problems such as long waiting times and travel costs. From the patient's point of view, telehealth allows them to avoid many medical appointments that require travel, waiting time and physical contact. It is also particularly useful for patients who live in remote areas or have difficulty traveling. In addition, thanks to telehealth, patients can see their doctor more often, regardless of their current location. The demand for telehealth services has increased, and it is expected to continue growing in the future. Dorsey and Topol (2016) provide an overview of the state of telehealth services, highlighting the potential of telehealth technologies to improve disease outcomes and reduce healthcare costs. These technologies can also provide great benefits for patients with chronic diseases and those who need continuous care. However, the article also discusses regulatory and reimbursement issues in the adoption of telehealth services, challenges and barriers in the adoption process. By discussing the current status and potential of telehealth services, this paper points out that it is a technology that can revolutionize healthcare delivery. Therefore, efforts should be made to further develop and expand telehealth services. Telemedicine, telehealth, and mobile health applications have the potential to revolutionize the way healthcare is delivered by providing patients with access to care regardless of their location. However, despite the many opportunities offered by these technologies, there are still significant barriers that need to be overcome to ensure their widespread adoption and integration into healthcare systems. In their article, "Telemedicine, telehealth, and mobile health applications that work: Opportunities and barriers," Weinstein et al. (2014) discuss these opportunities and barriers, as well as strategies for successful implementation and integration of telemedicine, telehealth, and mobile health applications into healthcare systems.

According to a recent systematic review and narrative analysis of telemedicine and patient satisfaction, telemedicine has been shown to increase patient satisfaction and reduce hospital readmission rates (Kruse et al., 2017). Additionally, telemedicine has been found to improve healthcare access and quality for rural and underserved populations (Dullet et al., 2017). With the ongoing development of telemedicine technologies, the field is poised to play an increasingly important role in the delivery of healthcare services to patients. This article by Ohannessian, Duong, and Odone (2020) calls for the integration and implementation of global tele-medicine into health systems during the COVID-19 pandemic. The article underlines the importance of tele-medicine and emphasizes that its use should increase in the fight against the COVID-19 pandemic. In addition, the authors address issues such as developing appropriate infrastructures for health systems to effectively implement tele-medicine, addressing legal and ethical issues, training of healthcare professionals, and acceptability of tele-medicine. A study by Haukipuro et al. (2018) focuses on the ethical implications of telehealth applications for patients in the aging process. We should not forget that telehealth services are connected to a computer and smart communication tools. Telehealth services can be performed on web and smart communication device applications. IOS and Android applications are the leading mobile applications. There are thousands of designed applications in the world. Their success rates and security scales are very important for users. It is seen that many studies have been done on this subject (Payo et al., 2021; Mendi et al., 2022; Messner et al., 2020; Miro et al., 2021; Payo et al., 2019). In addition, the World Health Organization is working very hard on this subject. It conducts many statistical analyzes on traditional and digital health systems (Kay et al., 2011). In addition, the European Union also provides many projects supports related to health and digitalization. This study is a result of the project called "Digital Youth Life Health Platform (DYL-HP)" numbered 2021-2-TR01-KA220-YOU-000049540, supported by the European Union and the Turkish National Agency (Soyguder, 2024).

This study was conducted to understand how telehealth applications can affect patients' lives and to assess the ethical appropriateness of these applications. Therefore, it addresses issues such as the effects of telehealth applications on patients' quality of life, as well as ethical issues and compliance with laws and regulations governing the use of telehealth applications. However, telehealth may not be suitable for all medical conditions. Diagnosis and treatment of some diseases may require a physical examination, which can make telehealth difficult. Also, some patients may not have access to digital technologies or may find it difficult to use technology. Therefore, telehealth may not be suitable for all patients and each case may require careful consideration. To provide a comprehensive understanding of the potential of telemedicine in transforming the delivery of healthcare services to patients, we will reference several key articles and studies throughout this paper. In this paper, we will provide an overview of telemedicine for patients, highlighting the benefits and challenges of this approach, as well as discussing the latest developments and innovations in the field.

**2. BENEFITS OF TELEHEALTH FOR PATIENTS**

From a patient perspective, telehealth offers a number of important benefits and greatly improves access to and experience of healthcare. Here are some of the key benefits of telehealth for patients:

* Ease of Access: By eliminating geographical distances, telehealth offers an inclusive solution for patients living in remote areas or with limited access to healthcare services. It provides quick access in cases such as emergencies or follow-up of chronic diseases.
* Time and Cost Savings: The time it takes to access traditional healthcare services and travel costs can be minimized through telehealth. Patients can get expert opinions without leaving their homes and manage their time more effectively.
* Personalized Healthcare: Telehealth offers personalized healthcare services that focus on the individual needs of patients. By analyzing patients' health data, healthcare professionals can create customized treatment plans and better adapt to patients' health conditions.
* Remote Monitoring and Management: For individuals with chronic diseases, telehealth offers remote monitoring and management. Patients can monitor their vital signs in their own homes and update their treatment plans by regularly connecting with healthcare professionals.
* Reduced Stigma and Privacy Concerns: For some patients, accessing in-person healthcare services can be difficult, especially for individuals with psychological or emotional issues. Telehealth reduces such concerns, allowing patients to access healthcare services in a more comfortable and confidential manner.
* Patient-to-Patient Communication and Support Groups: Telehealth platforms provide access to patient communities and support groups. This encourages the sharing of experiences between individuals with similar health conditions and increases solidarity between patients.
* Emergency Response: Telehealth facilitates rapid interventions for emergencies. Remote healthcare professionals can communicate with patients and give necessary instructions during emergencies.

**3. CHALLENGES OF TELEHEALTH FOR PATIENTS**

Telehealth applications may face some challenges. These challenges may prevent or make it difficult for patients to take full advantage of telehealth apps. Some key challenges may include:

* Technology access: Some patients may not have access to telehealth apps. In particular, the elderly or people unfamiliar with technology may experience difficulties accessing technology.
* Technology use: Using telehealth apps can be difficult for some patients. The complexity of the apps can make them difficult to use and prevent patients from fully utilizing telehealth apps.
* Service quality concerns: Some patients may be concerned that the quality of telehealth apps may be inferior to traditional face-to-face healthcare. These concerns may prevent patients from opting for telehealth apps.
* Limited personal interaction with health professionals: Telehealth apps can have limitations due to the lack of personal contact. This may occur because patients are unable to have personal interaction with health workers.

**4. PATIENT SATISFACTION WITH TELEHEALTH**

Telehealth has revolutionized healthcare services and has the potential to provide faster, accessible and personalized solutions to patients' health needs. In this context, patient satisfaction, which is a determining factor in the success of telehealth, is of increasing importance. Patient satisfaction is a key indicator of the user’s experience of telehealth services. This includes the ability of patients to communicate with health professionals in virtual environments, use remote monitoring algorithms and participate in teleconsultations. Many studies in the relevant literature reveal that patient satisfaction increases with the advantages offered by telehealth services. Telehealth services allow patients to overcome the problems of geographical distance, reduce waiting times, and access health services more frequently and quickly. These factors increase the value patients derive from telehealth services and positively affect their satisfaction. However, patient satisfaction is shaped not only by technological conveniences, but also by human-centered approaches in telehealth services. Strong communication with healthcare professionals, empathy, and respect for patient privacy are factors that determine the quality of telehealth services. As a result, patient satisfaction in telehealth, combined with fast access, personalized services, effective communication and the advantages offered by technology, positively affect patients' health experience. In this context, focusing on patient satisfaction in the design and implementation of telehealth services is important to ensure the sustainable success of these innovative healthcare solutions.

**5.** **ETHICAL CONSIDERATIONS IN TELEHEALTH**

Telehealth has undergone significant evolution with the digitalization and remote accessibility of healthcare services. However, along with the possibilities brought by this transformation, ethical considerations should also be an important focus. Patients are very sensitive to ethical issues such as privacy, security and proper use of health data when using telehealth services. The security of personal health information shared with healthcare professionals in virtual environments is a fundamental requirement for patients to use these services safely. Furthermore, ensuring informed consent in the use of telehealth applications is critical to support patients' understanding of this technology and their active participation in their own health processes. Therefore, strict application of ethical standards in the processes starting from the design of telehealth applications to service delivery is vital to ensure the trust of patients and to make the most of the potential advantages of this technology.

**6.** **FUTURE OF TELEHEALTH FROM A PATIENT PERSPECTIVE**

The evolution of telehealth is about to radically change the way patients participate, access and experience healthcare. In the future, patients will be increasingly empowered to access healthcare more quickly and easily. Remote consultations, health monitoring through mobile apps and wearables will enable patients to be more engaged in their own health journey. Moreover, technological innovations such as artificial intelligence and big data analytics will help patients better understand their health data and translate it into personalized health plans. From a patient perspective, future telehealth will be a catalyst for the transition to a healthier and connected lifestyle by providing individuals with the opportunity to manage and experience healthcare more closely. In this context, it is envisioned that future telehealth applications will play an important role in providing a user-friendly and effectively integrated experience that is responsive to patients' needs.

**7. CONCLUSION**

Telehealth represents a significant transformation in the healthcare sector, with a range of benefits to enable patients to participate more closely and effectively in healthcare services. These advantages include ease of access, time and cost savings, personalized healthcare services, remote monitoring, reduced stigma and emergency interventions, enrich the health experience of patients and provide healthcare professionals with the opportunity to deliver more effective care. Telehealth enables patient-to-patient communication and support groups, increasing solidarity and information sharing among patients and strengthening a sense of community. This is an important source of support, especially for individuals with chronic diseases. In traditional healthcare services, since digital technology and remote healthcare treatment systems are not used, it can create many negative consequences, such as carbon footprint, loss of time, travel expenses and poor psychological states. However, for telehealth to be successful, special attention needs to be paid to ethical standards and safety. Protecting patients' privacy and data security is a critical factor for the sustainability of this innovation. In conclusion, from a patient perspective, telehealth is leading a journey that expands access to healthcare, promotes individualized care and builds patient trust. This is an important step towards a more inclusive, accessible and patient-friendly future for the healthcare sector. As a result of this study, the advantages of digitalization and remote healthcare services in healthcare and the measures that need to be taken have been analyzed and discussed.

**CONFLICTS OF INTEREST**

The authors declared that there is no conflict of interest.

**REFERENCES**

Abut, T., & Soygüder, S. (2015). Motion control in virtual reality based teleoperation system. In 2015 23nd Signal Processing and Communications Applications Conference (SIU) (pp. 2682-2685). IEEE.

Abut, T., & Soyguder, S. (2017). Real-time control of bilateral teleoperation system with adaptive computed torque method. Industrial Robot: An International Journal, 44(3), 299-311.

Bashshur, R. L., Shannon, G. W., & Krupinski, E. A. (2016). The taxonomy of telemedicine. Telemedicine and e-Health, 22(8), 563-573.

Doniec, R. J., Piaseczna, N. J., Szymczyk, K. A., Jacennik, B., Sieciński, S., Mocny-Pachońska, K., Duraj, K., Cedro, T., Tkacz, E. J., & Glinkowski, W. M. (2022). Experiences of the Telemedicine and eHealth Conferences in Poland—A Cross-National Overview of Progress in Telemedicine. Applied Sciences, 13(1), 587. https://doi.org/10.3390/app13010587

Dorsey, E. R., & Topol, E. J. (2016). State of telehealth. New England journal of medicine, 375(2), 154-161.

Dorsey, E., Okun, M. S., & Bloem, B. R. (2020). Care, convenience, comfort, confidentiality, and contagion: the 5 C’s that will shape the future of telemedicine. Journal of Parkinson's disease, 10(3), 893-897.

Dullet, N. W., Geraghty, E. M., Kaufman, T., Kissee, J. L., King, J., Dharmar, M., ... & Blackburn, S. (2017). Impact of a university-based outpatient telemedicine program on time savings, travel costs, and environmental pollutants. Value in health, 20(4), 542-546.

Ekeland, A. G., Bowes, A., & Flottorp, S. (2010). Effectiveness of telemedicine: a systematic review of reviews. International journal of medical informatics, 79(11), 736-771.

Haukipuro, K., Ohinmaa, A., Winblad, I., & Linden, T. (2018). Ethical implications of e-health including telemedicine in the context of aging: a systematic review. Scandinavian Journal of Caring Sciences, 32(1), 11-19.

Hollander, J. E., & Carr, B. G. (2020). Virtually perfect? Telemedicine for Covid-19. New England Journal of Medicine, 382(18), 1679-1681. doi:10.1056/NEJMp2003539

Jnr, B. A. (2020). Use of telemedicine and virtual care for remote treatment in response to COVID-19 pandemic. Journal of medical systems, 44(7), 132.

Kay, M., Santos, J., and Takane, M. (2011). mhealth: New horizons for health through mobile technologies. World Health Organization, 64(7):66–71.

Kruse, C. S., Krowski, N., Rodriguez, B., Tran, L., Vela, J., & Brooks, M. (2017). Telehealth and patient satisfaction: a systematic review and narrative analysis. BMJ open, 7(8), e016242.

Kvedar, J., Coye, M. J., & Everett, W. (2014). Connected health: A review of technologies and strategies to improve patient care with telemedicine and telehealth. Health Affairs, 33(2), 194-199. doi:10.1377/hlthaff.2013.0992

Ma, Y., Zhao, C., Zhao, Y., Lu, J., Jiang, H., Cao, Y., & Xu, Y. (2022). Telemedicine application in patients with chronic disease: a systematic review and meta-analysis. BMC Medical Informatics and Decision Making, 22(1), 1-14.

Martin-Payo, R., Carrasco-Santos, S., Cuesta, M., Stoyan, S., Gonzalez-Mendez, X., and Fernandez-Alvarez, M. d. M. (2021). Spanish adaptation and validation of the user version of the mobile application rating scale (uMARS). Journal of the American Medical Informatics Association, 28(12):2681–2686.

Mendi, O., Sari, M. K., Stoyanov, S., and Mendi, B. (2022). Development and validation of the Turkish version of the mobile app rating scale MARS-TR. International Journal of Medical Informatics, 166:104843.

Messner, E.-M., Terhorst, Y., Barke, A., Baumeister, H., Stoyanov, S., Hides, L., Kavanagh, D., Pryss, R., Sander, L., Probst, T., et al. (2020). The German version of the mobile app rating scale (MARS -G): development and validation study. JMIR mHealth and uHealth, 8(3):e14479.

[Miro et al., 2021] Miro, J., Llorens-Vernet, P., et al. (2021). Assessing the quality of mobile health-related apps: interrater reliability study of two guides. JMIR mHealth and uHealth, 9(4):e26471.

Payo, R. M., Álvarez, M. F., Díaz, M. B., Izquierdo, M. C., Stoyanov, S. R., and Suárez, E. L. (2019). Spanish adaptation and validation of the mobile application rating scale questionnaire. International Journal of Medical Informatics, 129:95–99.

Ohannessian, R., Duong, T. A., & Odone, A. (2020). Global telemedicine implementation and integration within health systems to fight the COVID-19 pandemic: A call to action. JMIR Public Health and Surveillance, 6(2), e18810. doi:10.2196/18810

Sosnowski, R., Kamecki, H., Joniau, S., Walz, J., Klaassen, Z., & Palou, J. (2020). Introduction of telemedicine during the COVID-19 pandemic: a challenge for now, an opportunity for the future. European urology, 78(6), 820.

Tuckson, R. V., Edmunds, M., & Hodgkins, M. L. (2017). Telehealth. New England Journal of Medicine, 377(16), 1585-1592.

Vidal-Alaball, J., Acosta-Roja, R., Pastor Hernández, N., Sanchez Luque, U., Morrison, C., Narejos Pérez, S., ... Garcia Cuyàs, F. (2020). Telemedicine in the face of the COVID-19 pandemic. Atención Primaria, 52(6), 418-422. doi:10.1016/j.aprim.2020.04.005

Weinstein, R. S., Lopez, A. M., Joseph, B. A., & Erps, K. A. (2014). Telemedicine, telehealth, and mobile health applications that work: Opportunities and barriers. American Journal of Medicine, 127(3), 183-187. doi:10.1016/j.amjmed.2013.10.009

World Health Organization. (2010). Telemedicine: opportunities and developments in Member States: report on the second global survey on eHealth. World Health Organization.

Soyguder, S., (2024). Digital Youth Life Health Platform. Supported by the European Union and the Turkish National Agency. Project number: 2021-2-TR01-KA220-YOU-000049540. (2022), https://www.dyl-hp-aybu.org/

1. \*Resp author; e-mail: [alparslanguzey@gmail.com](mailto:a.guzey@iku.edu.tr) [↑](#footnote-ref-1)
2. Sorumlu yazar; e-posta: [hsynkarateke89@gmail.com](mailto:hsynkarateke89@gmail.com) [↑](#footnote-ref-2)
3. Resp author; e-mail: defendioglu@aybu.edu.tr [↑](#footnote-ref-3)
4. Resp author; e-mail: servetsoyguder@gmail.com [↑](#footnote-ref-4)
5. Resp author; e-mail: mkakgun@aybu.edu.tr [↑](#footnote-ref-5)
6. Resp author; e-mail: servetsoyguder@gmail.com [↑](#footnote-ref-6)