

# IE 482 Spring 2026 ECMO Project

## Designing Mobile ECMO Emergency Response Systems in Türkiye

Due Date: May, 9 23:59

### 1 General Information

Sudden cardiac arrest is one of the most time-sensitive emergencies in modern medicine. When circulation stops, irreversible neurological injury may begin within minutes, and the probability of meaningful survival decreases rapidly with time. Although cardiopulmonary resuscitation, defibrillation, and advanced life support are effective for many patients, some cases remain refractory to conventional treatment. For carefully selected patients, Extracorporeal Membrane Oxygenation (ECMO) can provide temporary circulatory and respiratory support by oxygenating blood outside the body and returning it to the patient. In cardiac arrest settings, this use is commonly referred to as Extracorporeal Cardiopulmonary Resuscitation (ECPR).

ECMO is not a definitive treatment in itself. Rather, it creates time for physicians to diagnose and treat reversible causes such as coronary occlusion, pulmonary embolism, myocarditis, or severe cardiogenic shock. It may also serve as a bridge to surgery, recovery, transplantation, or further intensive care management.

Despite its potential, ECMO is generally limited to specialized hospitals and requires highly trained personnel, costly equipment, and coordinated logistics. Therefore, in many cities, the main barrier is not whether ECMO exists, but whether it can be delivered quickly enough to the right patient.

From a systems perspective, there are two principal ways to improve access to ECMO. The first approach is to improve the location of ECMO capability by opening Mobile ECMO bases or ECMO-capable centers in optimal positions across the city. If bases are strategically selected, more districts can be covered within acceptable response times, backup coverage can be created, and inequalities between central and peripheral regions can be reduced. The second approach is to improve the mobility of ECMO resources by sending ECMO teams directly to patients through specialized vehicles, motorcycles, or rapid dispatch systems. This reflects international operational philosophies such as the Paris-style model, in which the ECMO team reaches the patient and cannulation occurs on scene, and the Minnesota-style model, in which the patient is transported rapidly to an ECMO-capable center through an optimized transport chain.

Together, these two perspectives allow the project to examine ECMO not merely as a medical device, but as a citywide emergency response system that can be designed, optimized, and adapted for future implementation in Türkiye.

## 2 Problem Definition

Türkiye possesses an expanding healthcare infrastructure, particularly in major metropolitan areas and tertiary centers. Several hospitals have the personnel and technical capability to provide ECMO support. However, current ECMO practice is largely hospital-based and depends on patient arrival to a capable center. In out-of-hospital cardiac arrest cases, transportation delays, traffic congestion, geographic inequality, and limited specialist availability may prevent timely access. Thus, the key challenge is not only whether ECMO exists, but whether it can be initiated quickly enough to influence survival.

This project proposes the development of a Mobile ECMO emergency response model for a pilot city in Türkiye. The objective is to investigate whether ECMO teams can be strategically positioned and dynamically dispatched in order to reduce delays and improve access. Instead of relying solely on hospital arrival, the project explores how ECMO capability can be mobilized across the city. The study is designed as a project that can later be adapted to other cities in Türkiye.

### 2.1 Available Dataset

The study will use a network dataset composed of 93 districts. Two matrices are available. The first is a  $93 \times 93$  inter-node distance matrix representing travel distance between districts. The second is a  $93 \times 93$  risk matrix representing the probability of disruption or reduced service between node pairs. These risks may reflect congestion, accidents, weather conditions, closures, or operational uncertainty.

### 3 Case Questions

#### 3.1 Question 1: Facility Location of Mobile ECMO Bases

There are 93 districts in the pilot city that may require emergency ECMO service. You are given the distances between these districts, and the reliability coefficient of each link connecting district pairs (if the coefficient is high, then the probability that the route is delayed, congested, or unusable is low).

The health authority plans to establish Mobile ECMO bases at selected hospitals or operational centers. These bases will host ECMO teams and vehicles that can be dispatched to eligible cardiac arrest patients.

1. Assume the authority will open 5 Mobile ECMO bases. Give a mathematical model that determines the locations of these bases while minimizing the longest response distance ( $R$ ) that an ECMO team must travel to reach a district. Assume each district should be covered by at least one base. Give your findings (results).
2. Now assume the authority decides that each district should be covered by at least two different Mobile ECMO bases within a range ( $R$ ), using at most  $p$  bases. Use the  $R$  value found in part a). How do you model this situation? Give your findings (results).
3. Conduct a sensitivity analysis on the number of Mobile ECMO bases ( $p$ ) for part b) and report the corresponding response radius ( $R$ ) values.
4. Consider part a) again. This time the authority also wants to consider route reliability. Each district must be assigned to a base through a link with a reliability coefficient greater than 0.70. Again, minimize the longest response distance ( $R$ ) that an ECMO team must travel.

#### 3.2 Question 2: Vehicle Routing and Dispatching of Mobile ECMO Units

1. Assume all Mobile ECMO vehicles are initially located at the main ECC (node 1 of the dataset). Vehicles travel with an average speed of 30 km/h. Determine the minimum number of vehicles required so that each district can be visited within 2 hours. Report the routes for each vehicle. (Each node should be visited at the end of the 2 hours. As the Mobile ECMO project is currently in the development and pilot phase, you need to test the operational capacity of the vehicles to handle sequential emergency calls. In this simulation, we assume a "High-Demand Scenario" where multiple patients (assume each node is a possible location of a patient) across different districts. When a Mobile ECMO vehicle reaches a node, it is assumed

the team performs the necessary life-saving stabilization. For the purposes of this model, the time spent on-site for treatment is considered negligible, allowing the vehicle to immediately proceed to the next patient in a neighboring district.)

2. Conduct a sensitivity analysis for part a). Decrease the total allowed response time from 2 hours to 1 hour in increments of 0.25 hours. Report the number of vehicles required at each step.
3. Now assume the ECC may be relocated. Among the Mobile ECMO bases opened in Question 1 part a), determine to which base the ECC should be moved. Use the same number of vehicles found in part a).
4. Now assume vehicles may be located at more than one Mobile ECMO base (chosen among the bases opened in Question 1 part a)). How many vehicles should be stationed at which bases in order to reach all districts within 1 hour?

#### **4 Bonus Question: Which Patient Should Receive ECMO?**

A Mobile ECMO network requires more than locations and vehicles. It also requires intelligent triage. ECMO cannot be sent to every cardiac arrest patient because it depends on a specialized team, expensive equipment, ICU capacity, and substantial time commitment. Therefore, you should also develop a patient selection mechanism. This may be a rule-based model, greedy or more advanced approaches like formulating an optimization model.

## Some Useful Information About the Case and Reports

1. You will be solving a **site selection problem**, not a site generation problem. This means you will **choose locations** for ECMO bases **from among the candidate sites** provided in the dataset, rather than generating new ones.
2. When writing your mathematical models:
  - Clearly state all **assumptions**,
  - Define **parameters, decision variables, objective function, and constraints**,
  - Provide the **full mathematical formulation**,
  - Include **explanations** for the objective function and each constraint.
3. Include an **Executive Summary** in your report summarizing the purpose, data, and overall findings and your approach to each question.
4. Structure your report into clear sections corresponding to each case question (**Q1a, Q2b etc.**) for readability and logical flow.
5. You do **not need to include any code** in your report (nor screenshots), unless you believe they are essential for understanding your approach.
6. Submit your project as a **single ZIP file** containing:
  - Your **Report (PDF format)**,
  - Your **code(s)**,
  - And any other materials you wish to include.

Ensure your code is runnable on other computers. If you use external data files (e.g., `.dat` for CPLEX), include them in your ZIP.

7. Name your ZIP and PDF files as `GroupNumber_ECMOProject`. For example, if your group number is 13, name the files: `Group13_ECMOProject.pdf` and `Group13_ECMOProject.zip`. You can find your group number on the course website.
8. If you encounter any issues or have questions, do not hesitate to contact with Egehan Uğraş and Alkim Abanuz.