GDZ Vehicle Assignment and Rerouting Systems Design Project

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Part 1

GDZ and Service Distribution

GDZ, one of the 21 electricity distribution companies in Türkiye and, ensures reliable distribution of electricity in Izmir and Manisa covering 13,123 km^2 of area across 47 districts and 2,383 neighborhoods and serving 3.6 million customers. The firm's headquarters lie in Bornova, Izmir. One of their services is fault maintenance, which is swift response to unexpected problems happening along the power grid throughout the day and night. This is done by dispatching some field teams to these problems throughout their shifts.

Field Teams and Vehicles

Each service center houses multiple field teams, who are considered uniform and do not exhibit different behaviors when under similar circumstances. If a team works more than one shift, then for that team, the individuals working in that team change from one shift to the next.

GDZ also has the capacity to dispatch extra teams when the workload becomes too high or too many urgent jobs are at hand. These teams are made up of workers working extraordinary shifts (they are called from their homes during out-of-work hours) and are usually paid at overtime rate.

Moreover, GDZ has two main types of vehicles, which are boom trucks (trucks equipped with cranes) and 4x2 cars. The vehicles are assigned to each service center respectively, meaning it is difficult to trade vehicles between service centers.

Vehicles, unlike teams, are not considered to be uniform. Each vehicle has different speeds, different rate of fuel consumption, and has an effect on the team's performance while completing a job.

Job Priority Types

There are two main types of job priorities defined by GDZ: Routing priority and operator priority.

- **Routing priority**: this is a weight given to each of the job types and ranges from 100 to 1000 in multiples of 100, where a weight of 100 represents the most urgent and important jobs. These weights do not change and are static.
- **Operator Priority**: this is a ranking system assigned by the operators in the Operations Coordination Center and are mostly subjective. They range from 1 to 10, with 1 being the most urgent job. This ranking takes into account the number of people affected, the sensitivity of affected facilities (hospitals, fire stations, etc.), and any possible mortal and/or monetary losses. In practice, this type of priority is more significant and important.

Job Cycle

The life time of a job can be expressed in Figure 1:

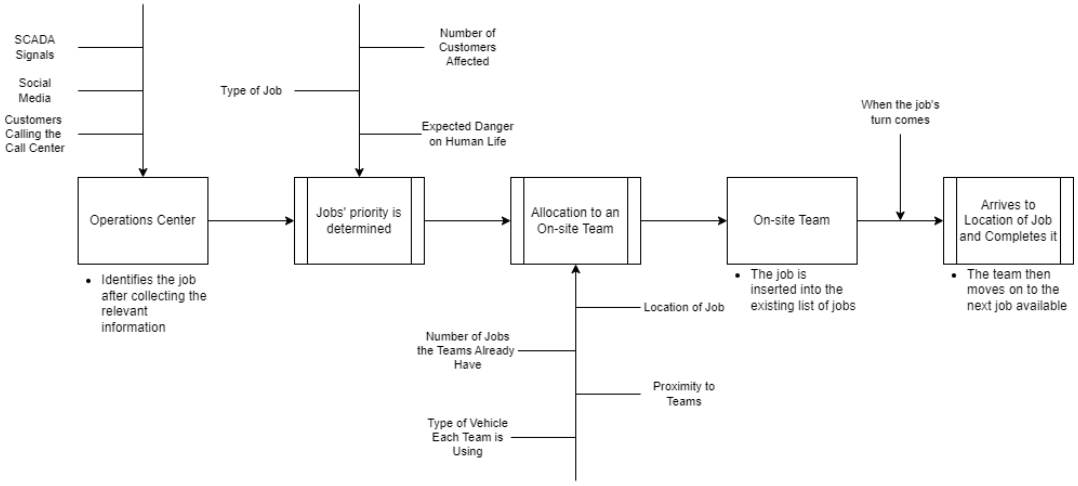


Figure 1: Flow chart of a task.

System Shortcomings, Problem Symptoms, and Company Expectations

Currently, the field teams are being overloaded with too many jobs that cannot be reasonably done within the current allocation and routing system. As such, there are too many jobs being left over and pushed onto the next shifts, causing too many delays.

The current system's problems are that it is too costly and is unsystematic. The identified symptoms are too much overtime, large number of incurred penalties, and no system or algorithm to perform the reassignments and reroutings.

Thus, GDZ expects a vehicle routing/rerouting system that reduces costs, increases customer satisfaction, and is able to assign newly incoming jobs to the field teams effectively

Part 2

Symptom

Upon examining historical data, it was possible to observe that the teams have been working a significant number of overtime hours. Figure 2 shows the additional working hours of the four Bornova teams over a period of 21 days:

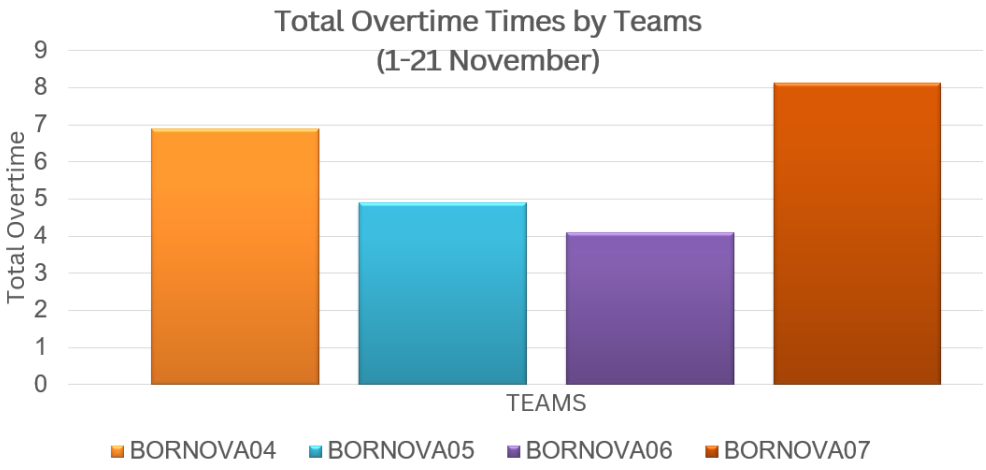


Figure 2: Overtime hours for selected teams between 1-21 November.

Excessive overtime hours entail two disadvantages for the company:

1. Compensating the workers for their overtime hours, whose rate is higher than that of normal hours.
2. Delaying the start of the teams in the next shift. The team working overtime may deliver the vehicle to the next shift late, and the next team waits for the vehicle at the center during this period. One such example is shown in Table 1:

Team	Shift	Normal Shift Hours	Start Time of the Shift	Ending Time of the Shift	Shift Time
BORNOVA05	A	07:00-15:00	07:32:13	17:29:32	09:57:19
BORNOVA05	B	15:00-23:00	17:41:47	23:03:39	05:21:52

Table 1: An extreme case of a shift's commencement being delayed due to the preceding team's tardiness.

Fishbone Diagram

The fishbone diagram for the overtime-related problem symptom is presented below:

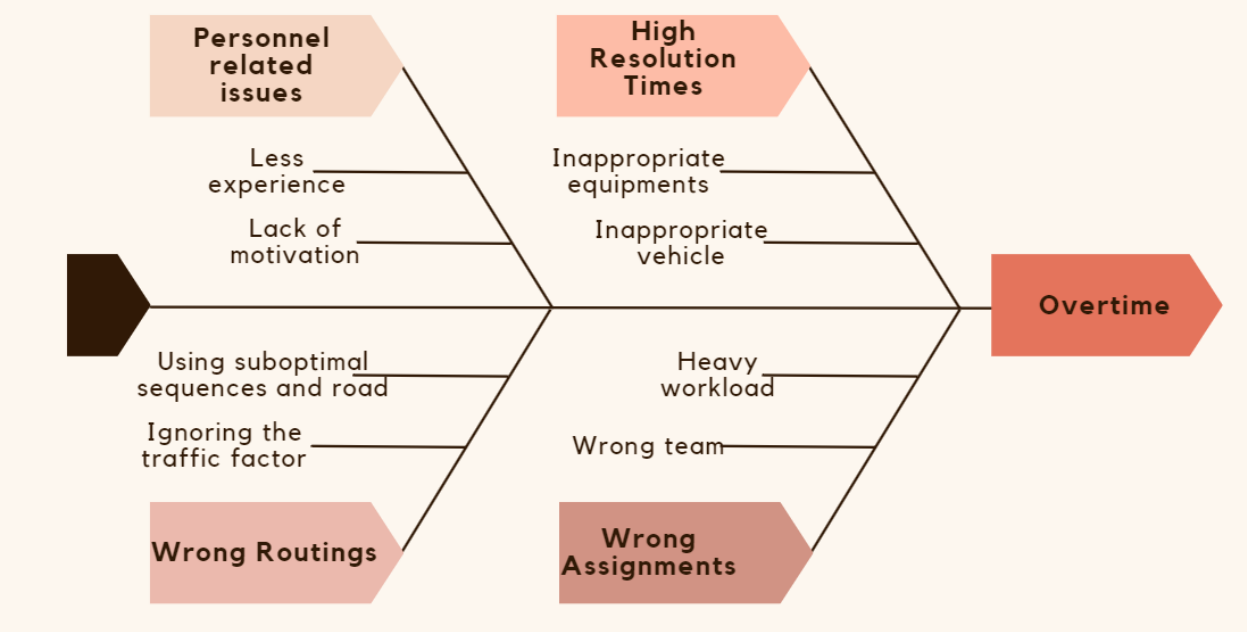


Figure 3: Fishbone diagram of the overtime-related problem symptom.

The systems where these elements belong to are listed below:

- Personnel related issues:
    - Less experience: IR
    - Less motivation: IR
- Wrong Routings:

    - Ignoring the traffic factor: IR
    - Using suboptimal sequences and road: NSI
- High Resolution Times:
    - Inappropriate equipment and vehicles: NSI
- Wrong Assignments:
    - Wrong team: NSI
    - Heavy Workload: NSI

Part 3

Problem Aspects

- **People and their roles:**
    - GDZ Fault Coordination Center/Project Advisor (Problem Owner)
    - SD Team (Problem Analysts)
    - Population of Izmir and Manisa (Problem Customers)
    - Field Team Members (Problem Users)
- **Worldviews:**
    - GDZ Fault Coordination Center:
        - A system that provides service to the population of Izmir and Manisa as well as its businesses.
    - SD Team:
        - A system that can be used as an SD project.
    - Population of Izmir and Manisa:
        - A system that provides them with electrical service 24/7.
    - Field team members:
        - A system that provides them with a job (in addition to their world view as part of the Izmir and Manisa populace).
- **Purposes:**
    - GDZ Fault Coordination Center:
        - To provide a service and reduce job lifetimes and increase customer satisfaction whilst also lowering costs.

- SD Team:
    - To establish a system that perform efficient reassignment and rerouting based on the firm's priorities that decreases costs and adheres to customer satisfaction importance.
- Population of Izmir and Manisa:
    - To have the least number of electricity-related problems as possible, and if they do happen, then they should be resolved as earliest as possible, without incurring any extra costs onto the consumers.
- Field team members and extra team members:
    - To do the tasks given to them by the Fault Coordination Center in the least time-consuming way possible while maintaining their wages.

- **Conflicts:**
    - Customers want fault lifetimes to be minimum but may be too expensive and is not feasible to provide by GDZ.
    - Team members would, of course, prefer to have the least number of jobs as possible, but that is not possible to sustain.
    - Dispatching an extra team might be necessary for GDZ, but unwanted by the team members in that extra team, because it means they need to be called from their homes into work.
- **Tradeoffs:**
    - Customer satisfaction and operation costs are directly proportional, if one increases, the other increases as well.
- **Relationships:**
    - Customers report faults to GDZ Fault Coordination Center.
    - GDZ determines the work schedule and working paradigm of the field teams.
    - GDZ relays the schedule to the field teams.
    - The field teams head out to the job sites and fix the issue.
- **Resources:**
    - Teams (and extra teams) and their working capacities
    - Workers

- Vehicles
- Fuel reserves of vehicles
- Repairing equipment and spare material used in repairing

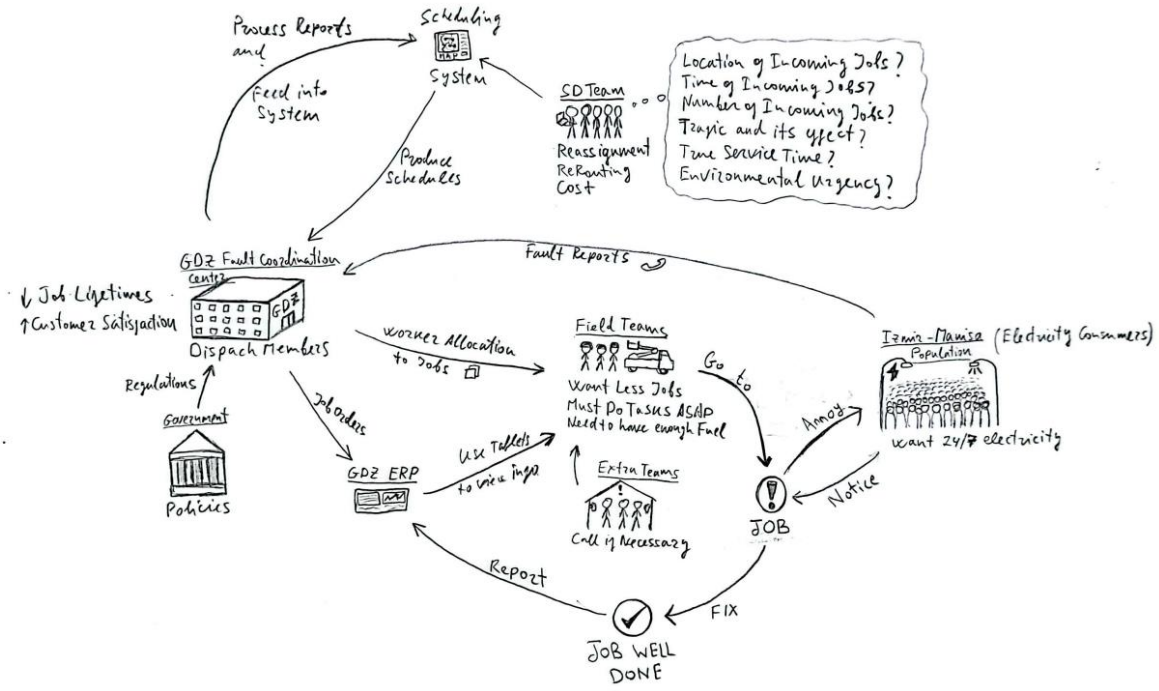
- **Structures and Processes (and how these affect each other):**
  - Structures:
    - GDZ Fault Coordination Center
    - Service Centers and their respective regions
    - Vehicles and the equipment they hold
    - Teams and extra teams
    - Regulations
    - Customers
    - Assignment and routing system
  - Processes:
    - Job orders and information about them
    - Assignment process of jobs to teams
    - Routing process of teams between jobs
    - Job completion and use of appropriate equipment and materials.
    - Dispatching extra teams
    - Payment of penalties
  - Interactions:
    - The teams are assigned to work inside the region that their service centers are responsible for.
    - The incoming jobs have an effect on the affected customers' status. (Neutral to frustrated)
    - The information about jobs comes from multiple sources, but mainly from customers, and is processed by the GDZ Fault Coordination Center, which then generates a schedule using the assignment and routing system, then assigns that job to a team and routes the team, according to the team's location and vehicle they are using.

    - Teams follow the routing process given to them, which affects the jobs' statuses. Teams use equipment and spare parts in the repairing process and consume fuel while moving from one place to another.
    - If too many jobs are coming in in a certain region, GDZ may dispatch extra teams in that region.
    - Regulations impose limits for the teams, which in turn affects the routing process; the regulations affect how the Fault Coordination Center assigns the jobs and routes the teams.
    - The efficiency of assignment and routing as well as the amount of resources available (which is constant throughout the shifts except for when extra teams are dispatched) can affect the satisfaction of customers, overall.

- **Uncertainties:**
    - Locations of incoming jobs
    - Time of incoming jobs
    - Number of incoming jobs
    - Traffic and its effect on travelling times
    - True service time
    - Environmental urgency of the jobs (people, facilities, and infrastructures affected)

Part 4

The rich picture can be found in the picture below:



Picture 1: Rich picture of the situation at hand.

Part 5

The chosen viewpoints are (in order of most detailed to least): Field workers, company advisor, and GDZ EDAŞ general manager.

Field Worker

1. Decision Maker: GDZ EDAŞ Field Worker

2. Decision Maker's Objective:

- To earn a satisfying living by employment
- Ensuring the quality and performance requirements of the works

3. Decision Criteria:

- To earn a satisfying living by employment
- Ensuring the quality and performance requirements of the works

4. Performance Measures:

- Monthly wage and benefits
- Performance assessments

5. Courses of Actions:

- Working overtime
- Paths to locations
- Work performance
- Breaks

6. Problem Context:

- Assignments and routes defined
- Shifts
- Roads and traffic
- Responsibility region and locations of centers
- Vehicles
- Team members
- Job orders(demand) and their locations
- Fatigue and work accidents

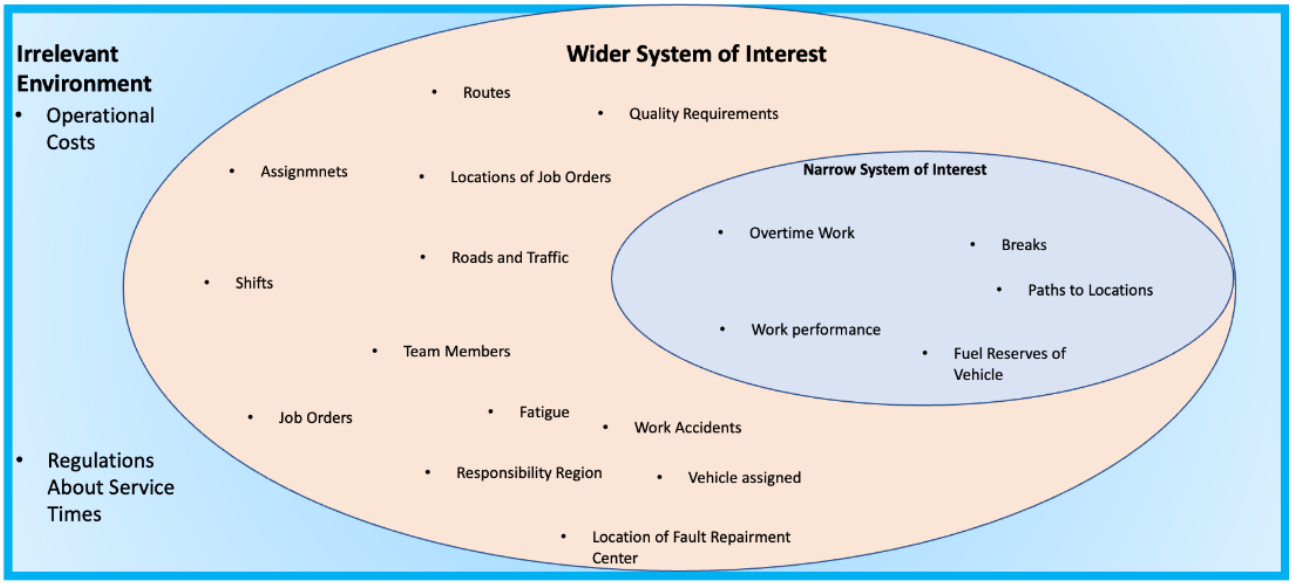


Figure 4: Hierarchy of systems - Field worker.

Company Advisor

1. Decision Maker: GDZ EDAŞ Fault Coordination Center

2. Decision Maker's Objective:

- Increasing customer satisfaction

- Reducing operational costs as a result of improving the existing vehicle
- assignment and routing system
- Developing a vehicle reassignment and rerouting system

3. Decision Criteria:

- Maximizing customer satisfaction
- Minimize operational costs
- Effective assignment of jobs to vehicles/teams

4. Performance Measures:

- Weighted completion times of jobs
- Total distance covered
- Costs due to overtime and delay
- Number of jobs assigned to a different vehicle in reassignments

5. Courses of Actions:

- Assignment and reassignment of jobs to vehicles/teams
- Routing and rerouting of jobs
- Jobs to be left to the next shifts

6. Problem Context:

- Fault repairment job orders (demand)
- Location of job orders, centers and vehicles/teams
- Types and number of vehicles in centers
- Number of the teams and workers in centers
- Responsibility areas of centers and teams
- Uniformity of teams
- Regulations

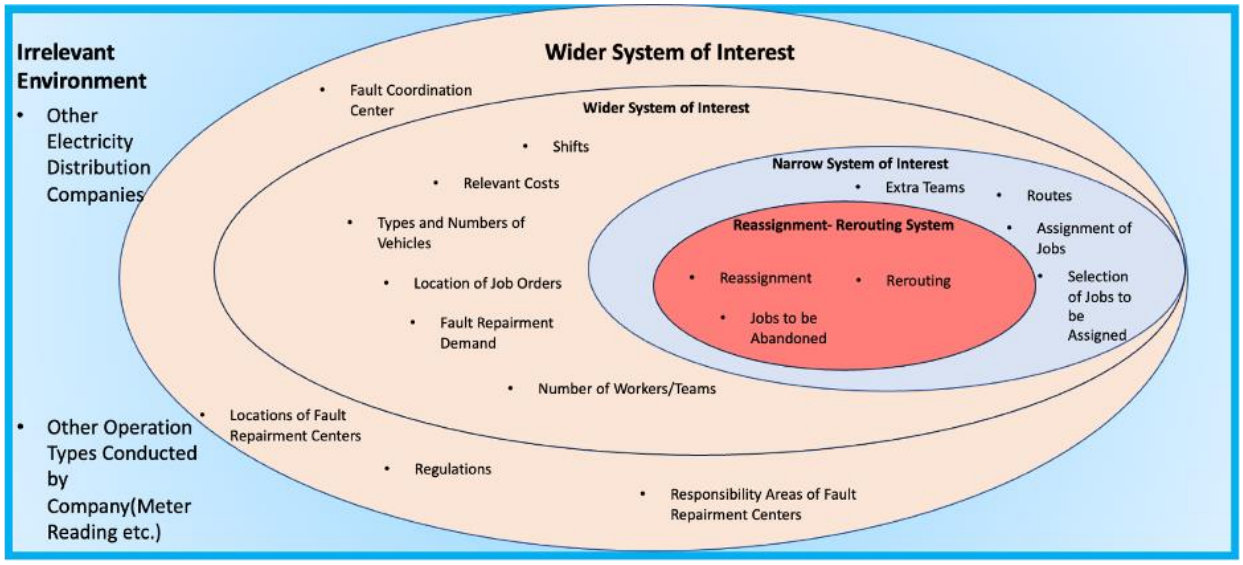


Figure 5: Hierarchy of systems - Company advisor.

GDZ EDAŞ General Manager

1. Decision Maker: GDZ EDAŞ General Manager

2. Decision Maker's Objective: To ensure the overall efficiency and effectiveness of the fault repair department, taking into account the overall budget

3. Decision Criteria:

- Financial responsibility and adherence to budget
- Overall organizational efficiency and effectiveness
- Compliance with regulatory service times

4. Performance Measures:

- Total operational costs at the organizational level
- Percentage of overall operations meeting regulatory service times
- Overall customer satisfaction with fault repairment services

5. Courses of Actions:

- Formulation and enforcement of company policies regarding fault repairment services
- Determining a budget in line with the overall objectives
- Total number of workers/vehicles
- Number of centers and their locations

6. Problem Context:

- Responsibility area
- Types and number of subscribers
- EPDK approved investment budget
- Regulations about service times
- TEDAŞ and EPDK regulations
- Company policies
- Maintenance of Infrastructure
- Electricity distribution infrastructure

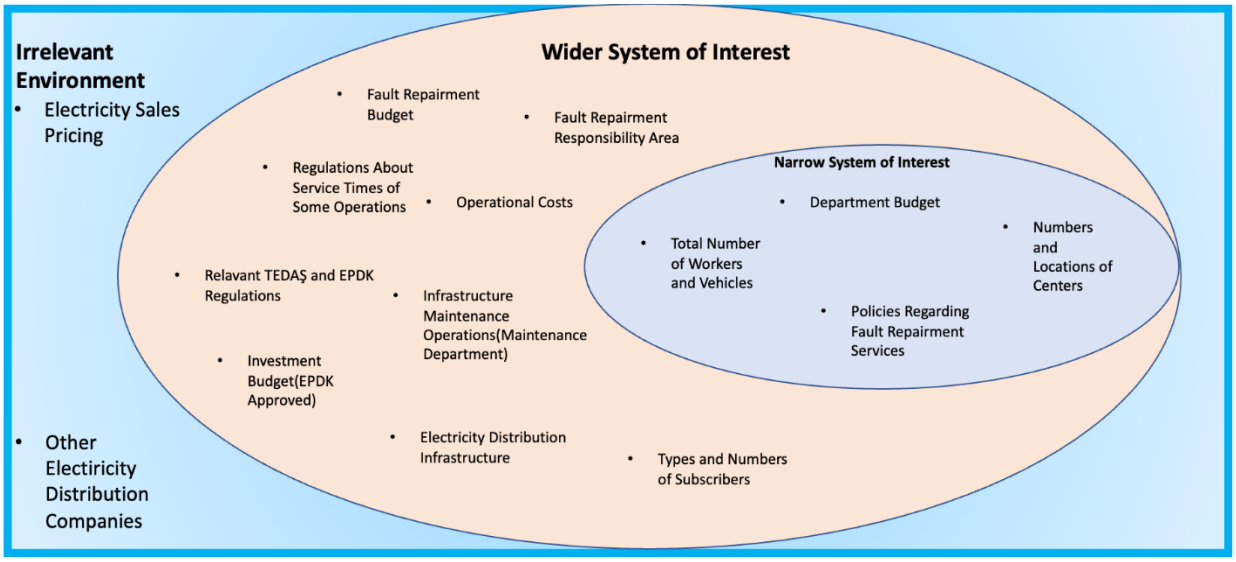


Figure 6: Hierarchy of systems - GDZ EDAŞ general manager.

Part 6

Three systems were obtained in Part 5. These are the systems from the viewpoints of a Field Worker, the Company Advisor at the Fault Coordination Center of GDZ, and the General Manager of the firm.

Field Worker

- **Observer's World View:**
  - Finishing the tasks assigned to themselves
  - Trying to start and finish the tasks in regular working hours
- **Components:**

- Vehicle
- Shifts
- Road and traffic
- Team members

- **Relationships:**
  - Vehicle availability depends on the shift. The shift also determines the team composition.
  - The status of roads and traffic affect the worker's decision-making in maneuvering the vehicle around.
- **Activities:**
  - Tending to job orders, going from one job to another, and deciding to work overtime or not, taking breaks.
- **Transformation:**
  - Live job → Fixed Job
- **Inputs:**
  - **Controllable Inputs:**
    - Overtimes
    - Breaks and allowances
  - **Uncontrollable Inputs:**
    - Road and traffic conditions
    - Job orders and their priorities
    - Weather conditions
- **Outputs:**
    - Total working hour
    - Total overtime
    - Number of tasks done

Company Advisor

- **Observer's World View:**
  - Maximizing the customer satisfaction by resolving the breakdowns as quickly as possible

- Minimizing the operational costs
- Monitoring the key performance indicators, such as weighted completion time
- Ensuring compliance with the regulations

- **Components:**
  - Current schedule
  - Live jobs and their types
  - Teams and their whereabouts, and the vehicles they are using
- **Relationships:**
  - The teams locations and their types as well as the type of the live jobs affect the current schedule.
  - The current schedule also affects the whereabouts of the teams later on.
  - The current schedule and the teams locations affect the status of the live jobs.
- **Activities and Transformation:**
  - Deferring tasks to the next shifts
  - Assignments and Reassignments
  - Routings and Reroutings
  - Assigning priorities to jobs
- **Inputs:**
  - **Controllable Inputs:**
    - Assignments and Reassignments
    - Routing and Reroutings
    - Shift planning
  - **Uncontrollable Inputs:**
    - Regulations
    - Job orders and its location
    - Location of teams and vehicles
    - Types and numbers of vehicles in the centers
- **Outputs:**
  - Weighted completion times
  - Total distance covered

- Costs
- Number of Jobs assigned to different teams in Reassignments

GDZ EDAŞ General Manager

- **Observer's World View:**
  - Enhancing organizational efficiency and effectiveness
  - Achieving compliance with the service times that regulations bring
- **Components:**
  - Operation costs
  - Building costs
  - Fraction of jobs that are done in the given feasible time interval
  - Average overtime hours worked
  - Number of hours worked in total
- **Relationships:**
  - Operation costs are determined by the total number of hours worked, which also affects fuel costs, vehicle costs, etc.
  - The total number of hours worked is affected by total overtime hours worked.
  - High building costs entail more jobs being done feasibly, and a high total number of hours worked also means that more jobs are done feasibly.
- **Activities and Transformation:**
  - Determining the number of vehicles, teams and workers
  - Allocating the budget to whole departments
  - Examining the key performance indicators regularly
- **Inputs:**
  - **Controllable Inputs:**
    - Number of vehicles
    - Number of workers
    - Number of teams
    - Worker wages in normal time and overtime
    - Number of centers and their locations
  - **Uncontrollable Inputs:**

- Responsibility area (Izmir and Manisa) geographic characteristics
- Prices of vehicles, fuels
- Workload due to upcoming jobs during the shift
- Subscribers

- **Outputs:**
  - Total costs
  - Customer satisfaction

Part 7

Narrow System of Interest

This focuses on assignment-reassignment and routing-rerouting of the work force, including selection and assignment of jobs, and routing. It also includes reassignment and rerouting system as a subsystem. Contains elements over which project advisor and SD team have control.

The reassignment and rerouting system has been determined as a subsystem of the narrow system of interest because it takes the routes and assignments in this system as inputs (see Figure A1 in Appendix A).

Wider System of Interest

This encompasses the entire fault repairment department, including vehicles/teams, job orders, centers, and responsibility areas.

Shifts, number and types of vehicles, number of workers/teams, locations of work orders and demand are placed on the environment of the narrow system of interest because project advisor and SD team do not have the authority to make a decision on these elements and take them as givens. Fault coordination center, locations, and responsibility area of centers and regulations are placed on the environment of wider system of interest since they affect the elements within it in some way.

Irrelevant Environment

Shows elements outside the system boundary. These elements do not interact with or affect the system in any meaningful way. These elements, such as other electricity distribution

companies, fall outside the scope of analysis. This also includes the other operations of other teams, such as the maintenance teams, since they do not affect the fault teams' activities nor are they affected.

Potential Environmental Fallacies

1. **Other operations conducted by the company**: This is considered to be part of the irrelevant environment, since operations like meter reading, maintenance, etc. are generally ignored and considered out-of-scope. However, maintenance applications applied to the electrical distribution infrastructure will affect the frequency of occurrence of faults and will also cause differences in the number of work orders created and consequently affect the assignment of jobs to teams. *IR → RE(NSI)*
2. **Number of teams and workers**: The project advisor may find that there is an overcapacity in some regions and may choose to decrease the number of teams - either fire them or place them in another region. *RE(NSI) → NSI*
3. **Shifts**: The project advisor may find it that there is non-value-adding time at the start of the shift and at the end (corresponding to teams leaving the center to the first job and the teams returning to the center after their last job) and may decide to change the shift structure to become two 12-hour shifts, three times a week for each worker instead of the current three 8-hour shifts, five times a week for each worker. *RE(NSI) → NSI*

Part 8

One of the subsystems presented in the hierarchy of systems is the Fault Coordination Center. It is a huge system on its own and contains multiple moving parts, whether that be information or personnel. Its transformation process can be best summarized as a system that receives vague, foggy information about job orders and sends out coherent job orders to GDZ's ERP system.

1. Efficacy: the quality of the generated job orders in terms of information and clarity. Measure: the number of complaints the field workers have about unclear job information.
2. Efficiency: information coming in compared to information coming out. Measure: number of information sources needed to identify a job order/problem successfully.

3. Effectiveness: effect of job order information accuracy on the job resolution time. Measure: GDZ, according to the data structure that they have, divides resolution times into 4 parts, as seen in Figure 7:

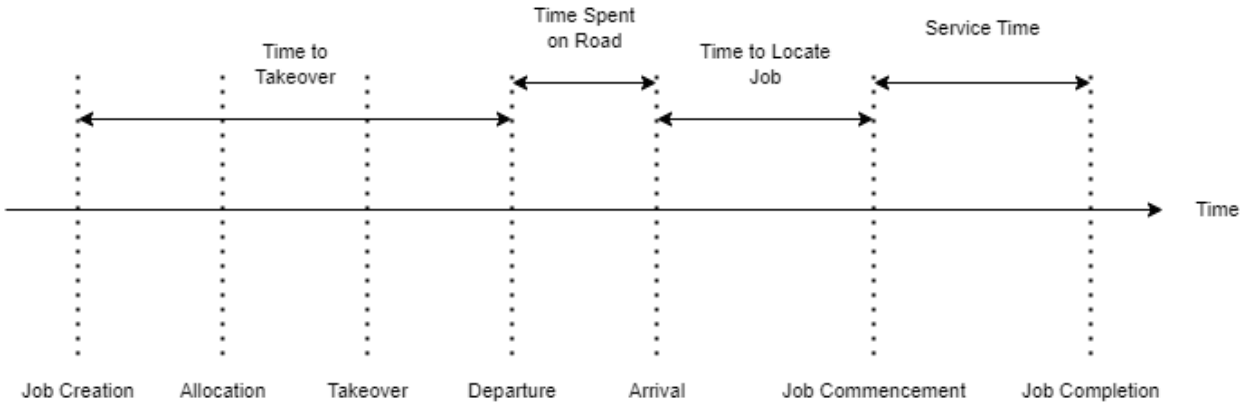


Figure 7: Stages of task completion.

The time to locate job decreases with the information clarity in job orders. So, this figure could be a measure of effectiveness. Note: this stage also includes other activities, but this is the main interpretation of it.

Part 9

The influence diagram of the problem from the general manager's point of view is displayed below:

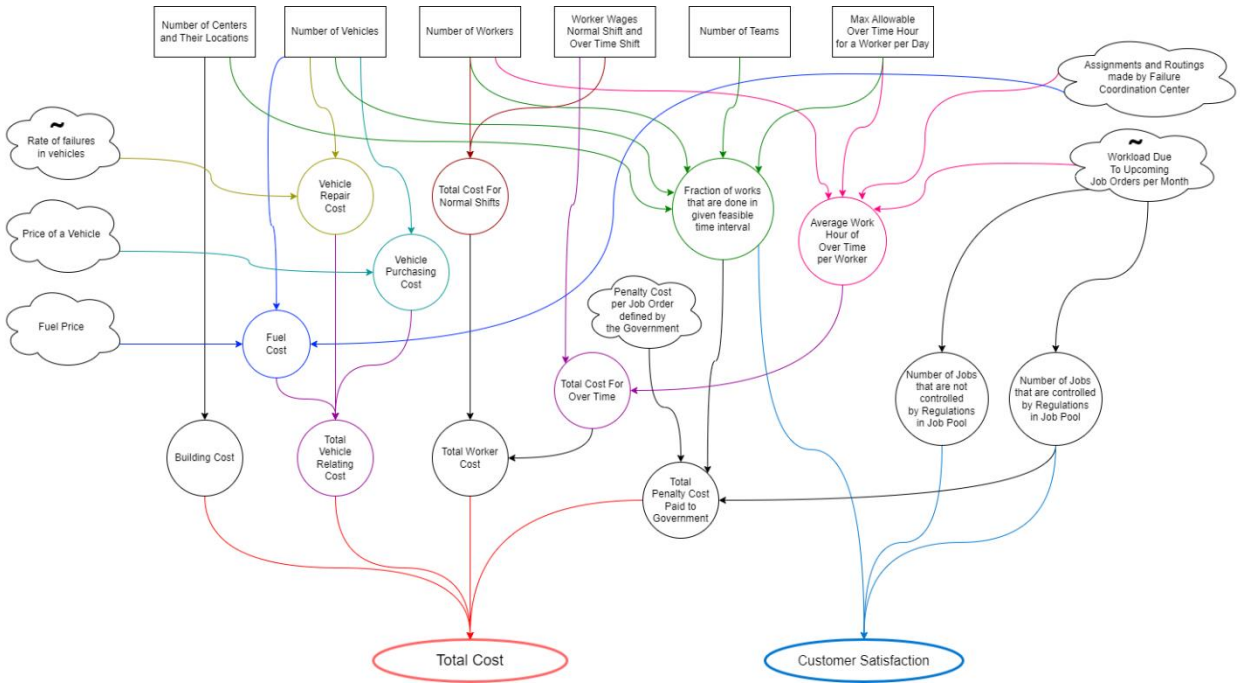


Figure 8: Influence diagram from general manager's point of view.

Part 10

In this project, **Hard OR Methodology** is used because the problem and its structure satisfy requirements for Hard OR Approaches.

First, in the problem context all the variables and situations are clearly defined and well-structured. Second, problem's boundaries are defined well in problem definition and isolated from its wider system; so, the role of analyst is focusing on Routing-Rerouting and Assignment-Reassignment. The problem interested is of a technical nature and it can be said that it is free of politics and people are mainly seen as passive objects and consensus among stakeholders can be reached easily. Optimization is possible in this scenario, and the decision maker has the power to implement the solution without any issues. Moreover, the problem's complexity can be best described as unitary, low technical complexity, but high probabilistic complexity due to the probabilistic nature of the job orders (Figure 9):

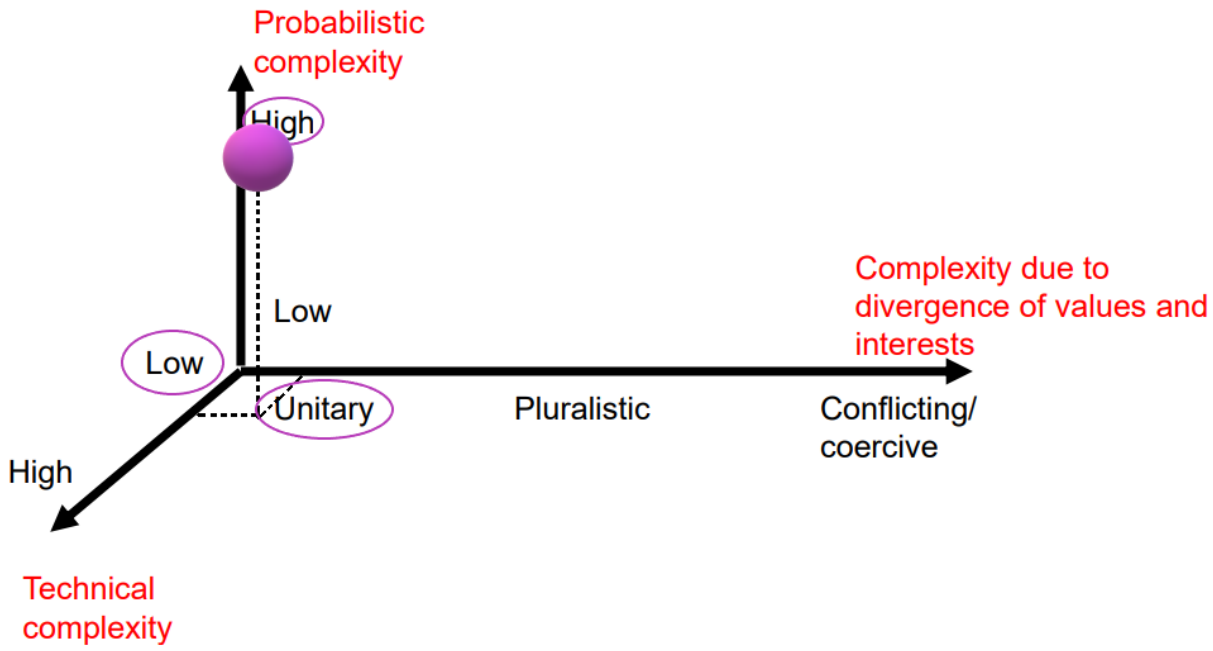


Figure 9: System complexity chart.

Appendix A

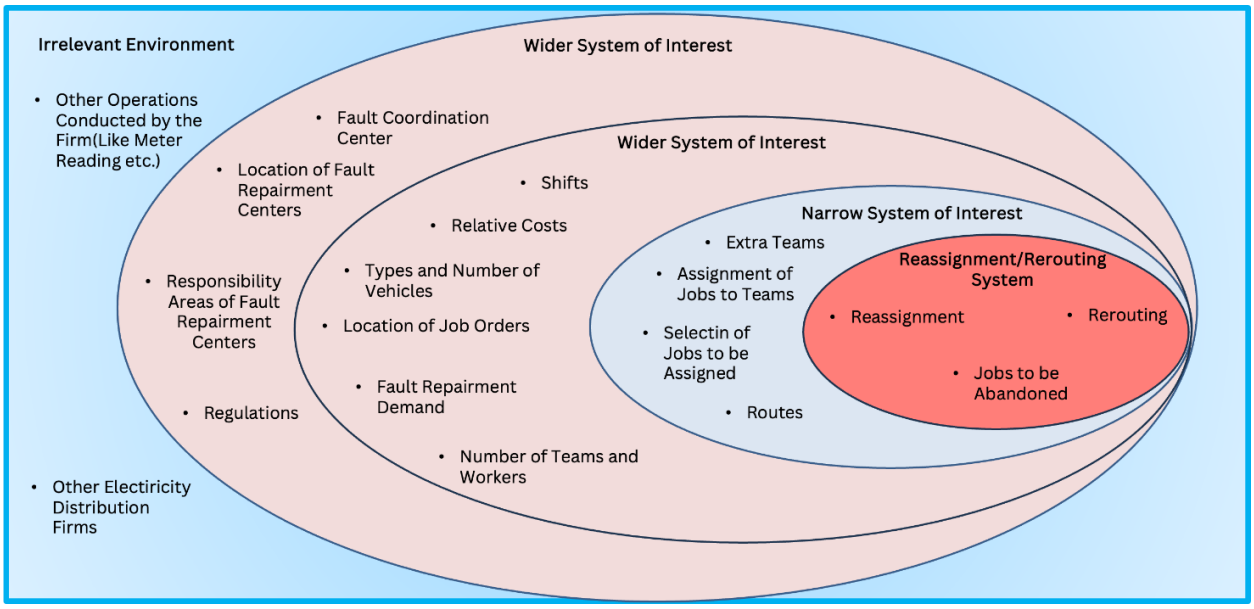


Figure A1: Hierarchy of systems from the viewpoint of the project advisor as well as the SD team.