Telecom Technician Routing and Scheduling (TRS) Problem

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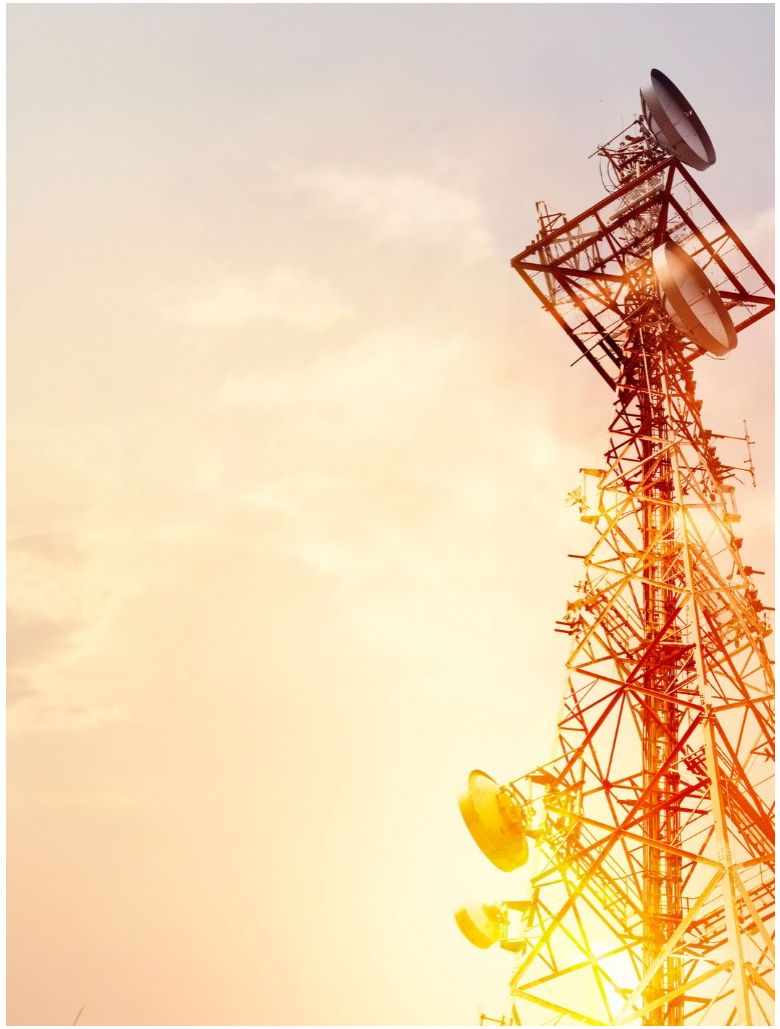
Outline

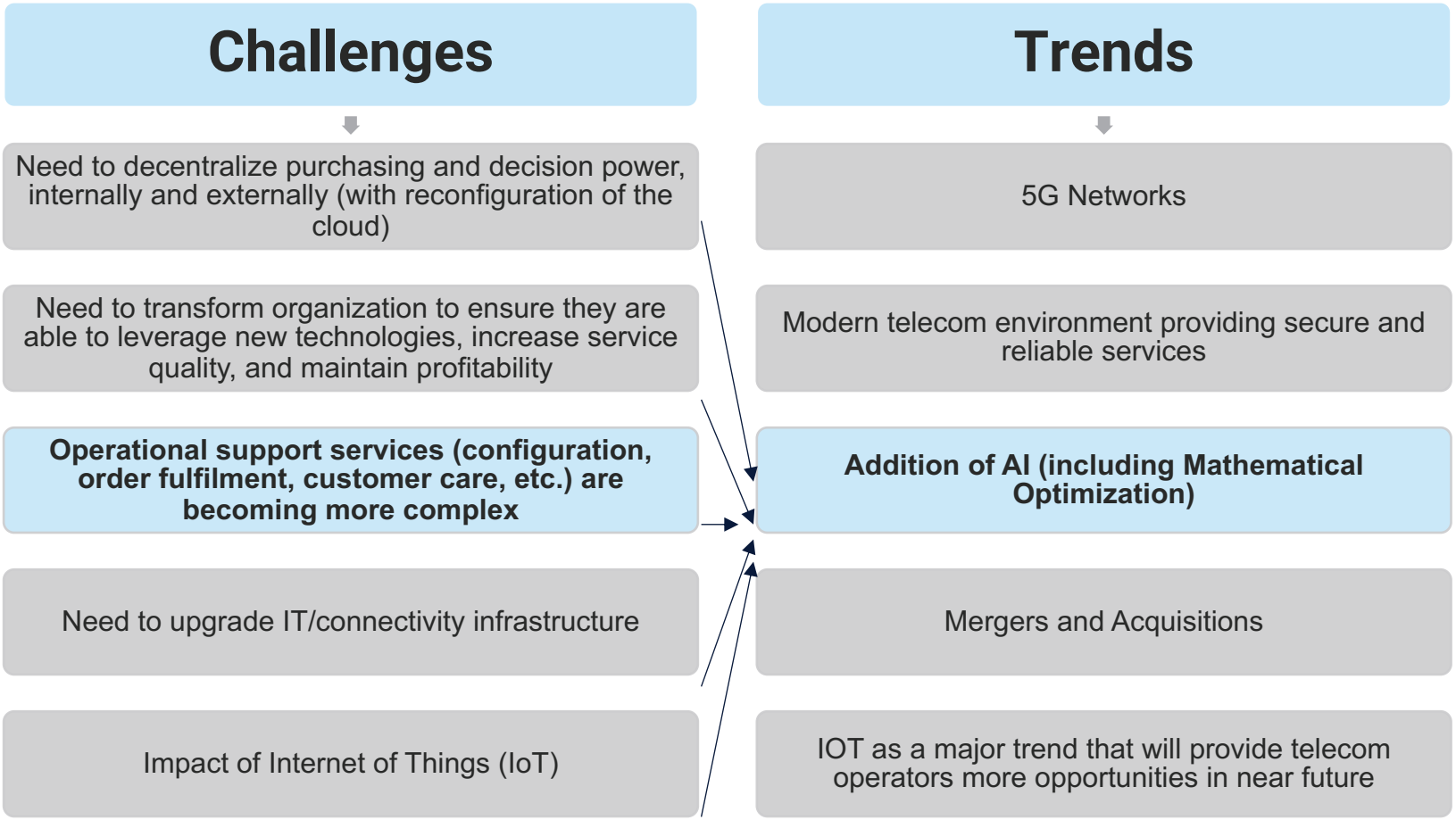
- Telecom Industry Challenges
- Introduction to the Technician Routing & Scheduling (TRS) Problem
- Problem Instance and Business Value Proposition
- TRS Demo



Telecom Industry Challenges

Pano Santos

Top Challenges and Trends in the Telecom Industry



Examples of the Use of Mathematical Optimization at the Strategic, Operational, and Tactical Levels

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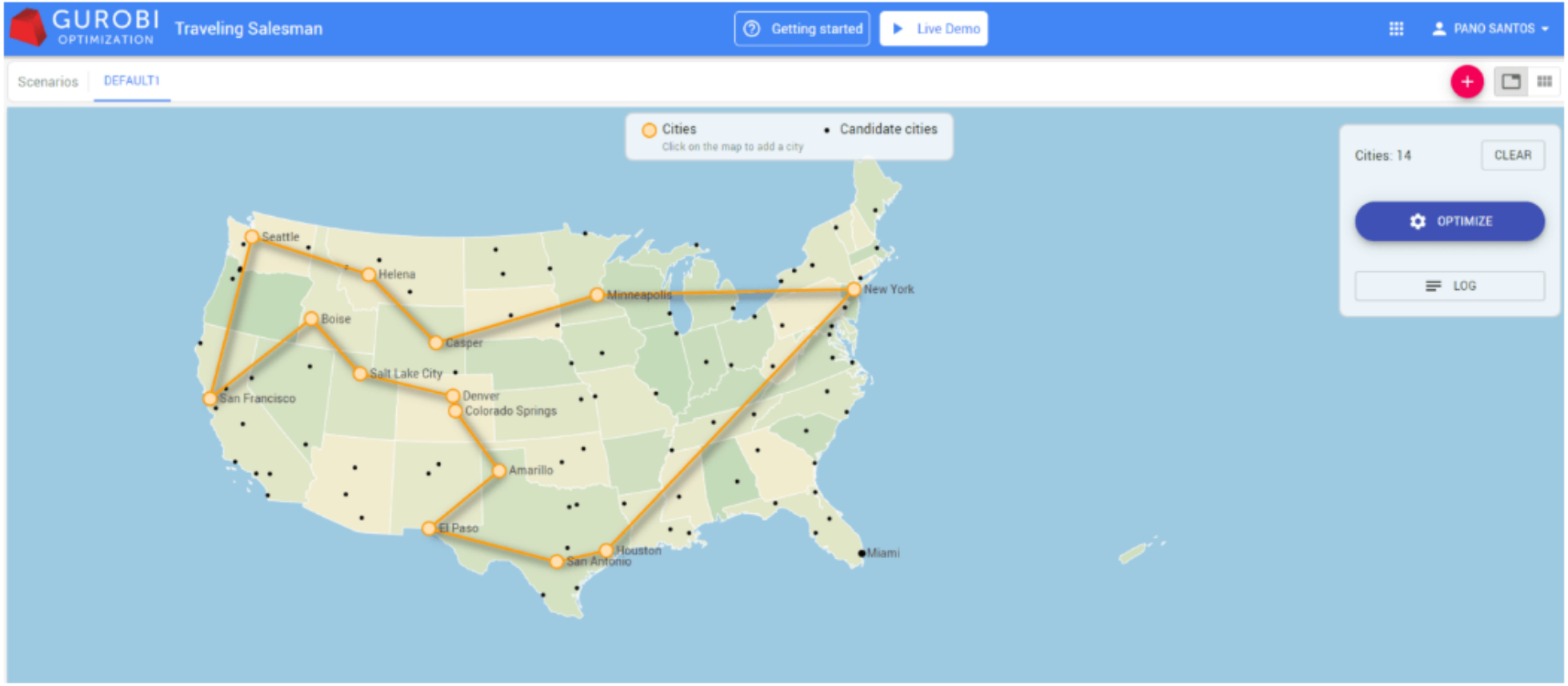
Capacity Planning	Customer Management	Cybersecurity	Demand Planning	Inventory Planning
Logistics Planning	Loss Forecasting	Workforce Planning	Product Pricing	Production Planning
	Supply Planning	Telecom Technician Routing and Scheduling (TRS) Problem	Marketing Campaign Optimization	

Vehicle Routing Problems Challenges

The Traveling Salesman Problem (TSP) is an instance of the Vehicle Routing Problem where a salesman needs to visit n cities, and he wants to find the shortest route that goes to each city once and returns to the origin city.



Vehicle Routing Problems Challenges…TSP Instance

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How difficult is the TSP to solve?

- A TSP with 100 cities has about $100! \approx 9.3 \times 10^{157}$
- This number is immense – much larger than the number of atoms in the universe, which is approximately 10^{80}.
- Even the fastest supercomputer called “Summit” – which can make mathematical calculations at a rate of 200 petaflops/second – will take an astronomical number of years to enumerate all the routes and determine the optimal one.

Vehicle Routing and Scheduling Problems Challenges

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Vehicle Routing and Scheduling Problems are much more challenging than the TSP.

- There are several salesmen.
- Each salesman has a limited time to do a tour.
- Each salesman is qualified to visit only a subset of cities.
- Each city has different requirements.
  - Visit time interval

Telecom Technicians' Routing and Scheduling Problem

Prof. Haitao Li

Telecom TRS Problem Challenges

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- **Maximize customer satisfaction**
  - Decreasing waiting time
  - Keep promised availability and fulfill the SLA
  - Delivery of new services and order fulfillment

- **Optimal use of resources**
  - Optimal assignment of resources entails assigning a technician:
    - With the right skills,
    - For the right job,
    - At the right time and location.

Business Situation: Dispatching Problem

- For the following day, a telecom company needs to assign a technician to each customer that has requested service that day.

- We assume that there is a booking system available to the customer service team that makes it possible to book a customer service request at the day and time requested.

- The booking system is based on the technicians' capacity and capability to perform the service job required.
    - On Tuesday June 24, 2020:
        - 60 hours of capacity available for Equipment Installation
        - 16 hours of capacity available for Repair-critical

Problem Description

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- A telecom firm operates multiple service centers to serve its customers.
- A service center hosts its technicians.
- A technician has multiple skills and available working capacity.
- A service order/job has known:
  - processing time,
  - customer-specified time window,
  - deadline of completing the service,
  - and skill requirements.
- Depending on the nature of the job, the firm assigns a priority score to it.
- A job is assigned to at most one technician who possesses the required skill.

Problem Description – 2

- **The basic technician routing and scheduling model (TRS0) involves three types of decisions:**
  1. The assignment of jobs to technician at all the service centers.
  2. The routing of each technician, i.e. the sequence/order of customers for a technician to visit.
  3. The scheduling of jobs, i.e. the timing for a technician to arrive at a customer and complete the corresponding job.
- **The firm's goal is to minimize the total weighted tardiness (lateness) of all the jobs, with their priority being the weights.**

Problem Description – 3

- **The following constraints must be satisfied:**
  - A technician departs from the service center and returns to the same service center after the assigned jobs are completed.
  - A technician's available capacity during the scheduling horizon cannot be exceeded.
  - A job is assigned to at most one technician who possesses the required skill.
  - **Customer satisfaction constraint**: A technician must arrive at a customer during a time window interval specified by the customer, and must complete a job before the deadline required by the customer.
  - A soft constraint is added to identify which job cannot be fulfilled.
  - Additional "soft constraints" are added to adjust/correct the customer-specified time-windows if needed.

Problem Statement

- **Maximize customer satisfaction**
  - Subject to the following constraints:
    - Customers' requirements constraints (due service time)
    - Technicians' capacity and capabilities
- **Determine:**
  - Technician-customers' assignments
  - Technicians' route and schedule
- **The model formulation is general enough to be applicable to a variety of Vehicle Routing Problems.**

Other Industry Applications of Integrated Routing and Scheduling

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Industry	Examples	Unique Features
Transportation	Transporting goods and people	Pickup-and-delivery, backhaul, bus tabling
Food	Food distribution and delivery	Perishability, cold chain
Healthcare	Homecare scheduling, vaccine delivery	Preference of timing, perishability of drugs
Emergency logistics	Distribution and delivery of emergency supplies for disaster relief	Limited capacity, timing, priority of regions
Utility	Technician service dispatching and scheduling	Priority of orders, customers' time windows

Problem Instance and Business Value Proposition

Pano Santos

Problem Instance (Base Scenario)

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Technicians' capacity and base depot location

	Albert	Bob	Carlos	Doris	Ed	Flor	Gina
Minutes	480	480	480	480	480	360	360
Depot	Heidelberg	Heidelberg	Freiburg im Breisgau	Freiburg im Breisgau	Heidelberg	Freiburg im Breisgau	Heidelberg

Job types, priority, and duration

	Priority	Duration (min)
Equipment Installation	2	60
Equipment Setup	3	30
Inspect/Service Equipment	1	60
Repair - Regular	1	60
Repair - Important	2	120
Repair - Urgent	3	90
Repair - Critical	4	60

Problem Instance (Base Scenario) – 2

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Customers' location and job requirements

	C1:Mannheim	C2: Karlsruhe	C3: Baden-Baden	C4: Bühl	C5: Offenburg	C6: Lahr/Schwarzwald	C7: Lörrach
Job type	Equipment Setup	Equipment Setup	Repair - Regular	Equipment Installation	Equipment Installation	Repair - Critical	Inspect/Service Equipment
Due time	8:00	10:00	11:00	12:00	14:00	15:00	16:00
Time Window	7:00-7:30	7:30-9:30	8:00-10:00	9:00-11:00	11:00-13:00	12:00-14:00	13:00-15:00

Travel times from depots to locations (in minutes)

	Heidelberg	Freiburg im Breisgau	Mannheim	Karlsruhe	Baden-Baden	Bühl	Offenburg	Lahr/Schwarzwald	Lörrach
Heidelberg	-	120	24	50	67	71	88	98	150
Freiburg im Breisgau	-	-	125	85	68	62	45	39	48
Mannheim	-	-	-	53	74	77	95	106	160
Karlsruhe	-	-	-	-	31	35	51	61	115
Baden-Baden	-	-	-	-	-	16	36	46	98
Bühl	-	-	-	-	-	-	30	40	92
Offenburg	-	-	-	-	-	-	-	26	80
Lahr/Schwarzwald	-	-	-	-	-	-	-	-	70
Lörrach	-	-	-	-	-	-	-	-	-

Possible Model Extensions

There might be known costs associated with assigning a technician to satisfy a customer request, and penalty costs of completing the job late. In addition, there might be revenues associated with the customer service request.

- In this case, the objective function could be maximizing total gross profits.

There might be multiple objectives like:

- Maximizing customer satisfaction and maximizing technician utilization.

Business Value Proposition

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- Provides “What if analysis” capabilities.
- Improves customer satisfaction by allowing customers to define service due time and reduce the time window for starting the service job.
- Enables optimal adjustments on assignment, routing, and scheduling decisions due to last minute changes regarding technicians’ availability or customer requirements.

TRS Demo

Dan Jeffrey and Pano Santos

TRS Demo

- **Test scenario**
  - One technician with 600 min (10 hrs.) of capacity

TRS Demo

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- **Base scenario**
  - There are enough technicians with the required skills to satisfy all customer requirements.

```
Optimal solution found (tolerance 1.00e-04)
Best objective 0.000000000000e+00, best bound 0.000000000000e+00, gap 0.0000%

Albert assigned to Customer1 (Equipment Setup) in Mannheim. Start at t=24.00.
Albert assigned to Customer2 (Equipment Setup) in Karlsruhe. Start at t=150.00.
Gina assigned to Customer3 (Repair - Regular) in Baden-Baden. Start at t=68.00.
Gina assigned to Customer4 (Equipment Installation) in Buehl. Start at t=240.00.
Flor assigned to Customer5 (Equipment Installation) in Offenburg. Start at t=360.00.
Doris assigned to Customer6 (Repair - Critical) in Lahr/Schwarzwald. Start at t=300.00.
Carlos assigned to Customer7 (Inspect/Service Equipment) in Loerrach. Start at t=360.00.

Albert's route: Heidelberg -> Mannheim (dist=24.0, t=24.00, proc=30.0) -> Karlsruhe (dist=53.0, t=150.00, proc=30.0) -> Heid
elberg (dist=50.0)
Bob is not used
Carlos's route: Freiburg im Breisgau -> Loerrach (dist=48.0, t=360.00, proc=60.0) -> Freiburg im Breisgau (dist=48.0)
Doris's route: Freiburg im Breisgau -> Lahr/Schwarzwald (dist=39.0, t=300.00, proc=60.0) -> Freiburg im Breisgau (dist=39.0)
Ed is not used
Flor's route: Freiburg im Breisgau -> Offenburg (dist=45.0, t=360.00, proc=60.0) -> Freiburg im Breisgau (dist=45.0)
Gina's route: Heidelberg -> Baden-Baden (dist=67.0, t=68.00, proc=60.0) -> Buehl (dist=16.0, t=240.00, proc=60.0) -> Heidelb
erg (dist=71.0)

Albert's utilization is 38.96% (187.00/480.00)
Bob's utilization is 0.00% (0.00/480.00)
Carlos's utilization is 32.50% (156.00/480.00)
Doris's utilization is 28.75% (138.00/480.00)
Ed's utilization is 0.00% (0.00/480.00)
Flor's utilization is 41.67% (150.00/360.00)
Gina's utilization is 76.11% (274.00/360.00)
Total technician utilization is 29.01% (905.00/3120.00)
```

TRS Demo

- **Scenario 1**
  - Technicians are working at half of their capacity.
  - Customer 5 requires an urgent service and its due time is at 00 min (7:00 beginning of the planning horizon).

```
Optimal solution found (tolerance 1.00e-04)
Best objective 1.241000000000e+04, best bound 1.241000000000e+04, gap 0.0000%

Albert assigned to Customer1 (Equipment Setup) in Mannheim. Start at t=24.00.
Gina assigned to Customer2 (Equipment Setup) in Karlsruhe. Start at t=50.00.
Bob assigned to Customer3 (Repair - Regular) in Baden-Baden. Start at t=67.00.
Nobody assigned to Customer4 (Equipment Installation) in Buehl
Flor assigned to Customer5 (Equipment Installation) in Offenburg. Start at t=45.00. 105.00 minutes late.
Doris assigned to Customer6 (Repair - Critical) in Lahr/Schwarzwald. Start at t=300.00.
Carlos assigned to Customer7 (Inspect/Service Equipment) in Loerrach. Start at t=480.00.

Albert's route: Heidelberg -> Mannheim (dist=24.0, t=24.00, proc=30.0) -> Heidelberg (dist=24.0)
Bob's route: Heidelberg -> Baden-Baden (dist=67.0, t=67.00, proc=60.0) -> Heidelberg (dist=67.0)
Carlos's route: Freiburg im Breisgau -> Loerrach (dist=48.0, t=480.00, proc=60.0) -> Freiburg im Breisgau (dist=48.0)
Doris's route: Freiburg im Breisgau -> Lahr/Schwarzwald (dist=39.0, t=300.00, proc=60.0) -> Freiburg im Breisgau (dist=39.0)
Ed is not used
Flor's route: Freiburg im Breisgau -> Offenburg (dist=45.0, t=45.00, proc=60.0) -> Freiburg im Breisgau (dist=45.0)
Gina's route: Heidelberg -> Karlsruhe (dist=50.0, t=50.00, proc=30.0) -> Heidelberg (dist=50.0)

Albert's utilization is 32.50% (78.00/240.00)
Bob's utilization is 80.83% (194.00/240.00)
Carlos's utilization is 65.00% (156.00/240.00)
Doris's utilization is 57.50% (138.00/240.00)
Ed's utilization is 0.00% (0.00/240.00)
Flor's utilization is 83.33% (150.00/180.00)
Gina's utilization is 72.22% (130.00/180.00)
Total technician utilization is 54.23% (846.00/1560.00)
```

TRS Demo

- **Scenario 2**
  - Technicians are working at half of their capacity.
  - All customers require their service to be completed at 60 min (8:00).

```
Optimal solution found (tolerance 1.00e-04)
Best objective 2.366200000000e+04, best bound 2.366200000000e+04, gap 0.0000%

Gina assigned to Customer1 (Equipment Setup) in Mannheim. Start at t=24.00.
Bob assigned to Customer2 (Equipment Setup) in Karlsruhe. Start at t=50.00. 20.00 minutes late. End time corrected by 20.00
minutes.
Ed assigned to Customer3 (Repair - Regular) in Baden-Baden. Start at t=67.00. 67.00 minutes late. End time corrected by 37.0
0 minutes.
Nobody assigned to Customer4 (Equipment Installation) in Buehl
Flor assigned to Customer5 (Equipment Installation) in Offenburg. Start at t=45.00. 45.00 minutes late. End time corrected b
y 15.00 minutes.
Doris assigned to Customer6 (Repair - Critical) in Lahr/Schwarzwald. Start at t=39.00. 39.00 minutes late. End time correcte
d by 9.00 minutes.
Carlos assigned to Customer7 (Inspect/Service Equipment) in Loerrach. Start at t=48.00. 48.00 minutes late. End time correct
ed by 18.00 minutes.

Albert is not used
Bob's route: Heidelberg -> Karlsruhe (dist=50.0, t=50.00, proc=30.0) -> Heidelberg (dist=50.0)
Carlos's route: Freiburg im Breisgau -> Loerrach (dist=48.0, t=48.00, proc=60.0) -> Freiburg im Breisgau (dist=48.0)
Doris's route: Freiburg im Breisgau -> Lahr/Schwarzwald (dist=39.0, t=39.00, proc=60.0) -> Freiburg im Breisgau (dist=39.0)
Ed's route: Heidelberg -> Baden-Baden (dist=67.0, t=67.00, proc=60.0) -> Heidelberg (dist=67.0)
Flor's route: Freiburg im Breisgau -> Offenburg (dist=45.0, t=45.00, proc=60.0) -> Freiburg im Breisgau (dist=45.0)
Gina's route: Heidelberg -> Mannheim (dist=24.0, t=24.00, proc=30.0) -> Heidelberg (dist=24.0)

Albert's utilization is 0.00% (0.00/240.00)
Bob's utilization is 54.17% (130.00/240.00)
Carlos's utilization is 65.00% (156.00/240.00)
Doris's utilization is 57.50% (138.00/240.00)
Ed's utilization is 80.83% (194.00/240.00)
Flor's utilization is 83.33% (150.00/180.00)
Gina's utilization is 43.33% (78.00/180.00)
Total technician utilization is 54.23% (846.00/1560.00)
```

TRS Demo (Conclusion)

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- **What to do with the results**
  - Planners can take action to fix the problem or at least alert customers about potential service issues.

Thank You

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