Disruption management in vehicle routing: problems and models

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EPSRC
Pioneering research and skills

Theory LANCS Practice

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Personal research interests

- Green logistics
  - Time-dependent vehicle routing
- Arc routing
  - Winter gritting
  - Prize collecting arc routing with time-dependent data
- Disruption management

Introduction to Disruption Management

- A disruption is "a state during the execution of the current operation, where the deviation from plan is sufficiently large that the plan has to be changed substantially" (Clausen et al., 2001).

Approaches to disruptions

- Based on Yu & Qi (2004)
  - Contingency planning
  - Stochastic modelling
  - Robust optimisation

  In-advance planning
  - Pure rescheduling
  - Disruption management

  Real-time re-planning

Types of disruption in VRP

- Vehicle breakdown
- Blocked links
- Order release delay

Order release delay example

- Newspaper and magazine distributor in UK.
- Deliver 5 million newspapers and 2.1 million magazines every day
- What to do when there is a delay in printing certain newspapers?

Types of disruption in VRP

- Vehicle breakdown
- Blocked links
- Order release delay
- Delays at customers
- New orders
- Cancelled orders

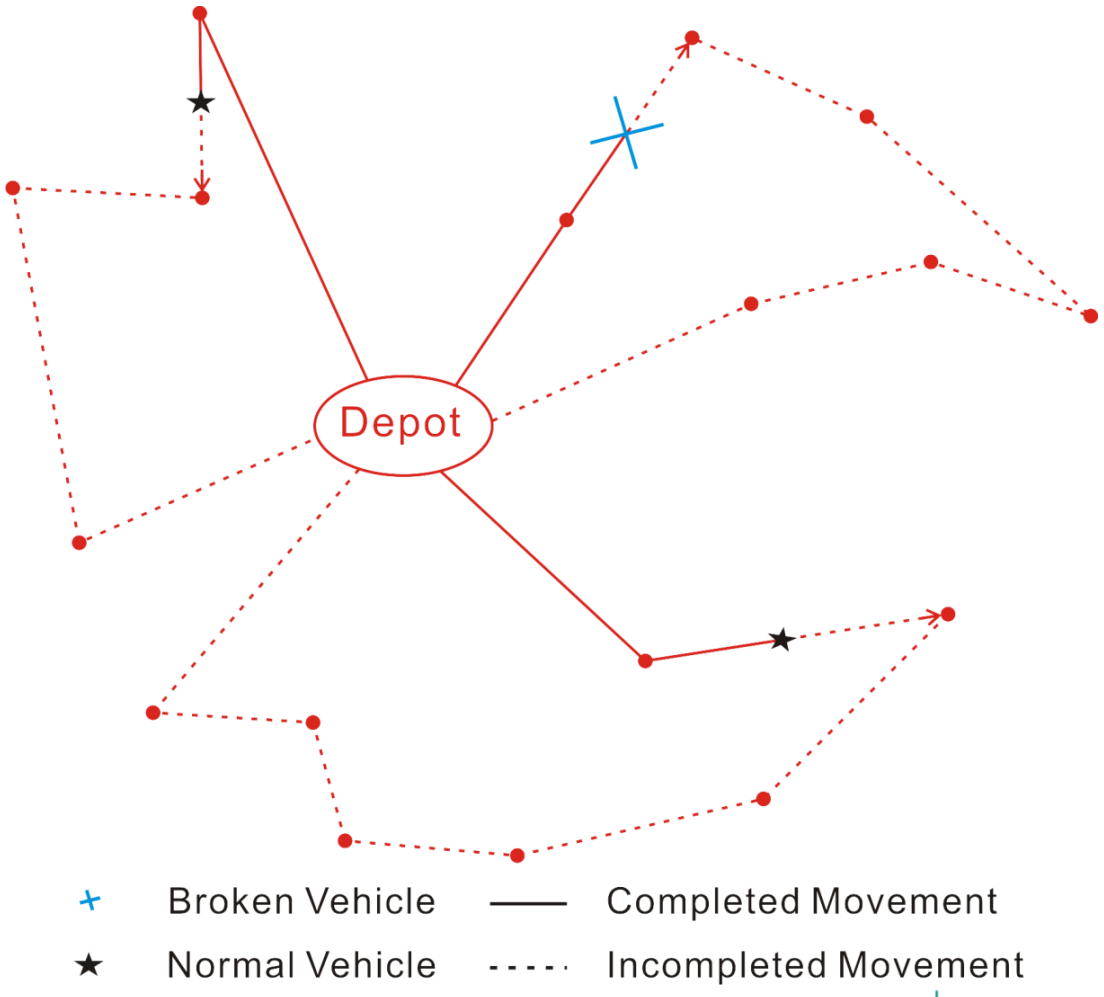
Key Factors

- Revised costs
- Response time
- Multiple objectives (e.g. delivery times)
- Additional constraints

Disrupted VRP with Vehicle Breakdown

- Type of VRP: CVRP
- No time windows, no delay cost or cancellation
- Type of commodity: Single commodity
- Objective: 1) Minimise number of vehicles used
  2) Minimise total distance
- Assumptions:
  - Only one vehicle is broken down
  - 1 extra vehicle is available at the depot
  - Vehicles are carrying their full capacity when they leave the depot
  - A vehicle cannot be diverted until it has visited its current destination.

Disrupted VRP with Vehicle Breakdown



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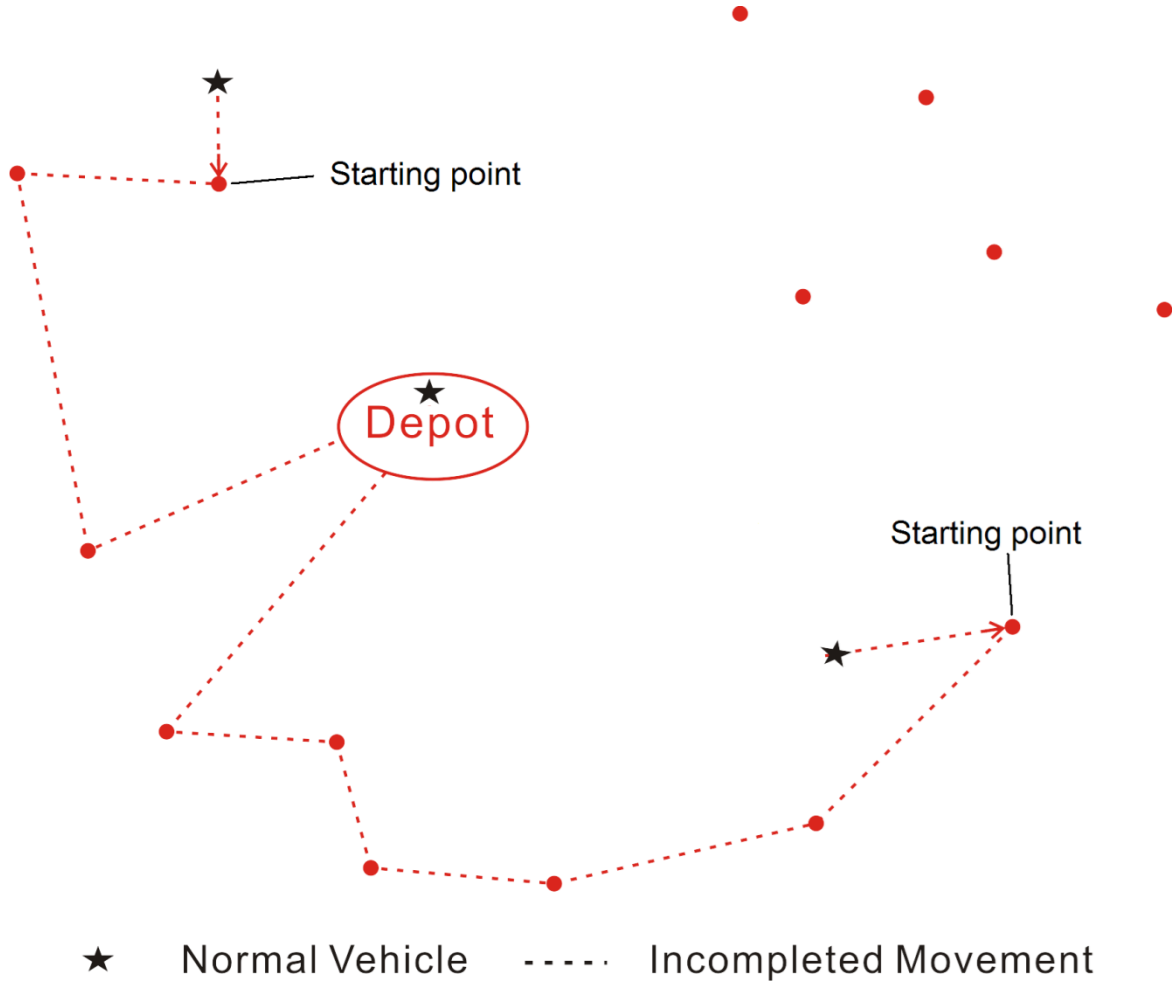
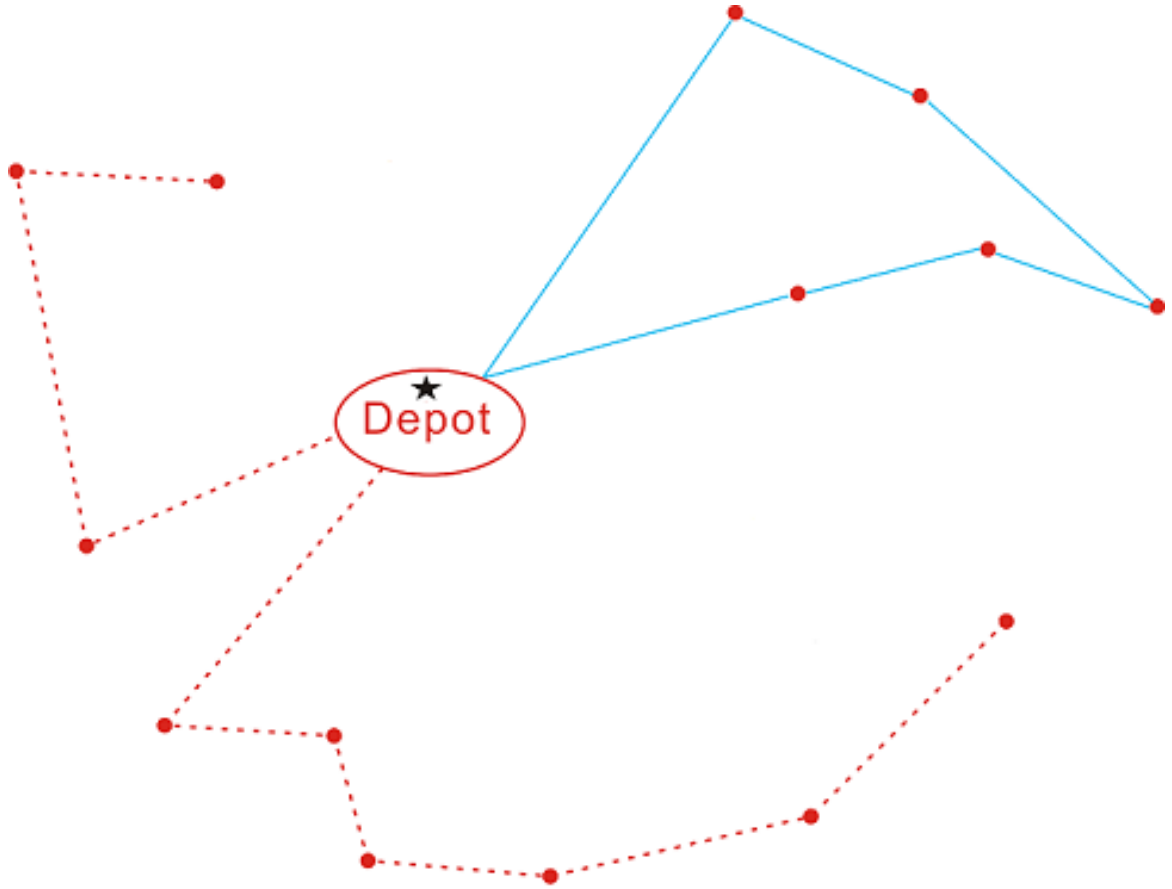
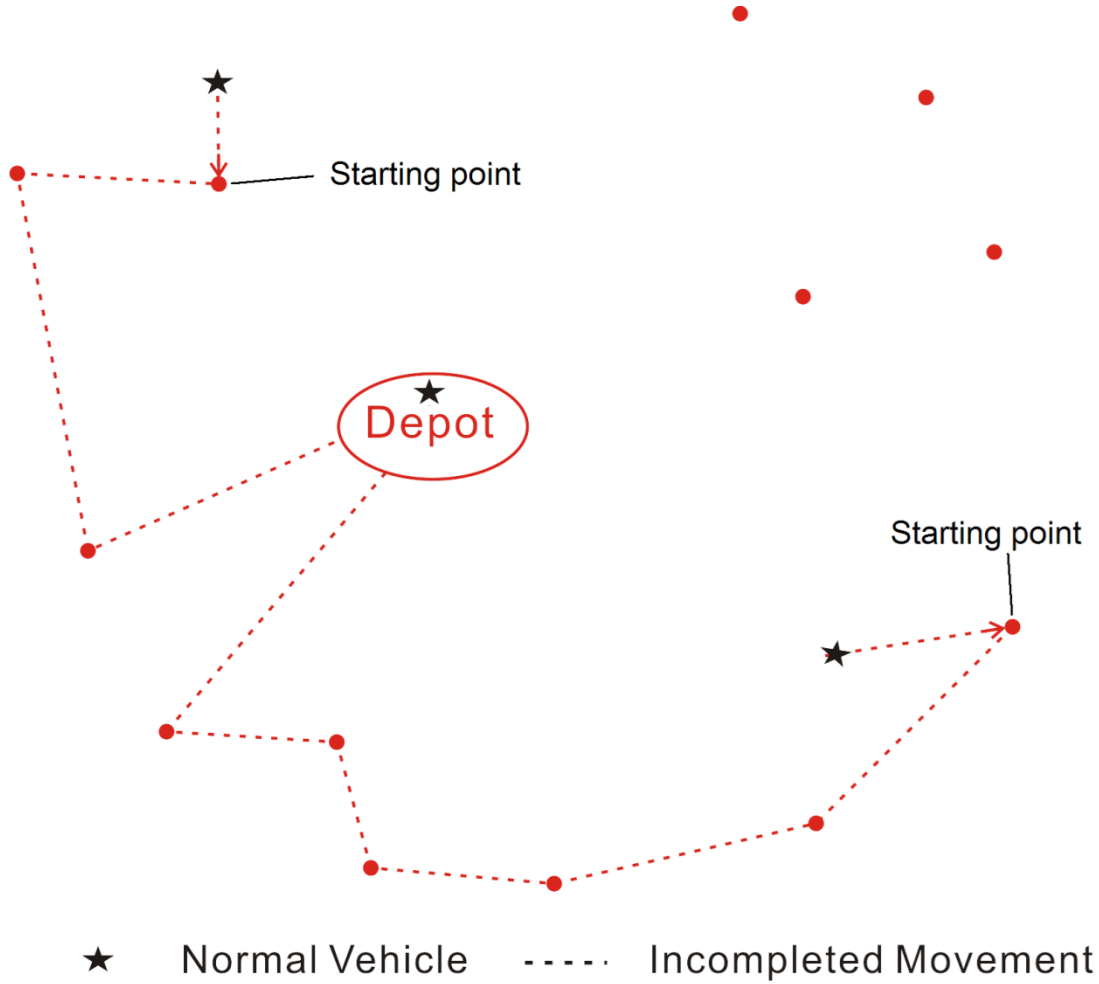
Disrupted VRP with Vehicle Breakdown



“Easy” solution



Structure of Problem – Open VRP with fixed end points

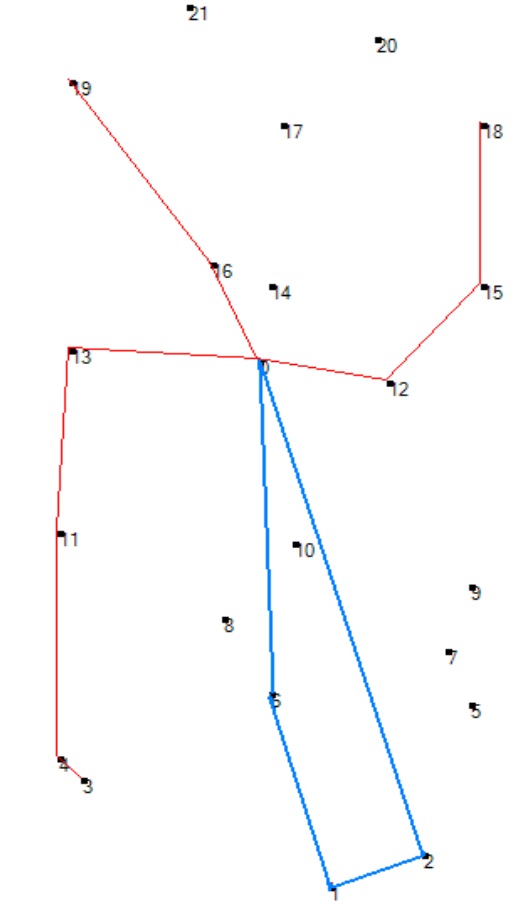


Solution methods

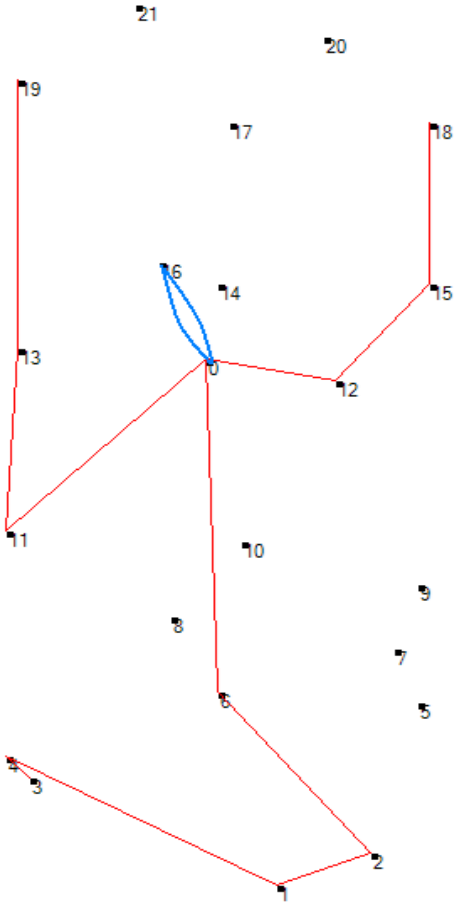
- Tabu Search heuristic
- Exact method for Open VRP
- Tested on standard VRP benchmark examples with added disruptions at different stages

- Details in: Mu Q., Fu Z., Lysgaard J. and Eglese R. (2011) Disruption management of the vehicle routing problem with vehicle breakdown. Journal of the Operational Research Society, Vol. 62(4), pp 742-749.

Example (based on E-n22-k4)



Easy Plan (cost 233)



New Plan (Cost 212)

Conclusions from study

- The tabu search heuristic finds a feasible solution quickly (within 1 min).
- The solution is optimal in 92% of problems tested and significantly better than the "Easy Solution".
- Although the exact method usually gives the optimum quickly, there are some cases where it fails in the time limit.

Order release delay

- Objectives …
- Minimise total travel distance
- Minimise delay to services
- Minimise overtime for drivers
- So it is a multi-objective problem

Details in:

Mu Q. and Eglese R. (2013) Disrupted capacitated vehicle routing problem with order release delay. Annals of Operations Research, Vol. 207, pp 201-216.

Solution approaches

- Keep routes the same, but delay a subset of vehicles until supplies arrive
- Send out all the vehicles, but use a set of rules to decide which are under-loaded and by how much
- Tabu Search based heuristic devised for this problem, starting from the solutions above
- Worthwhile improvements are possible

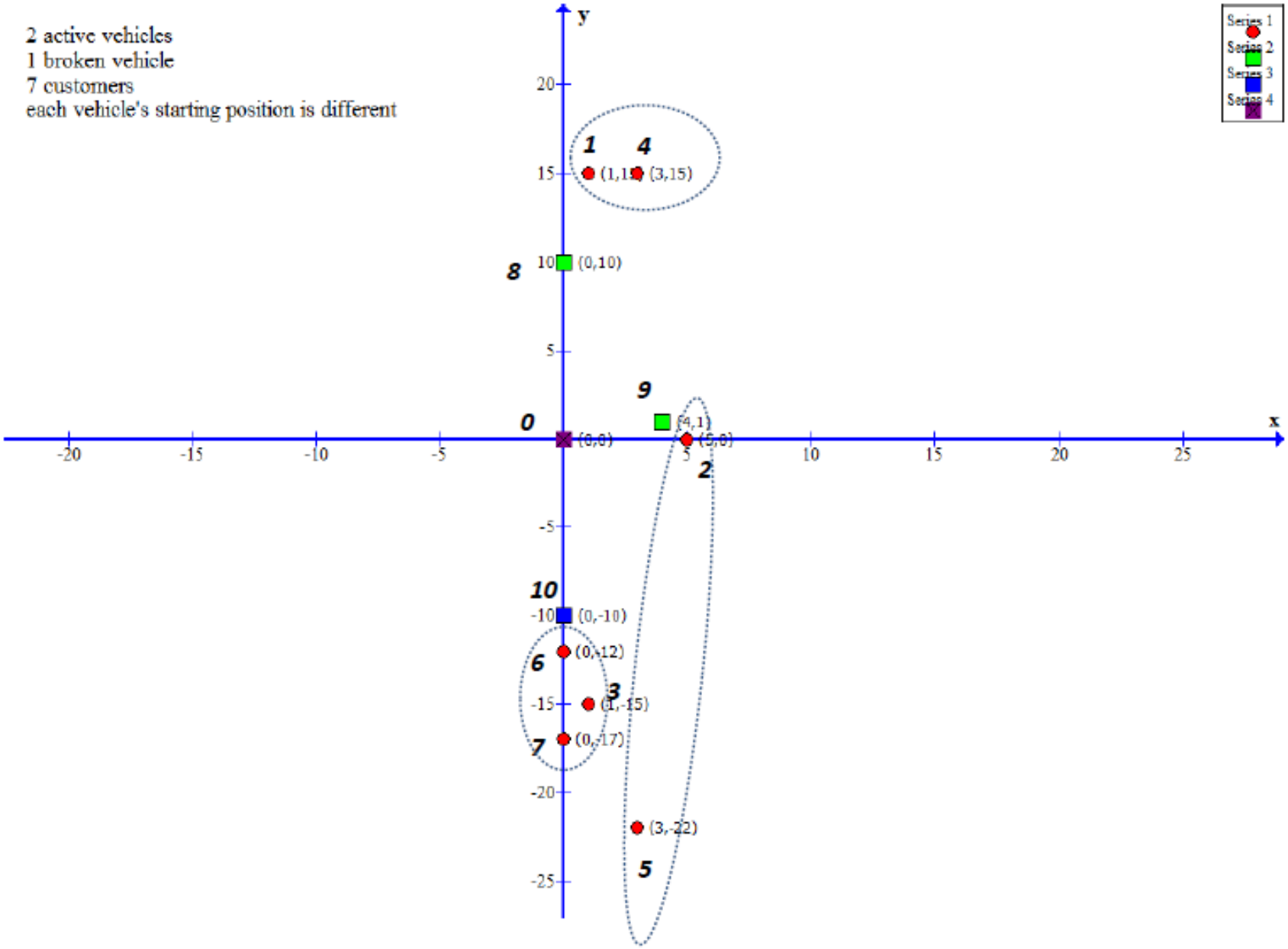
Disrupted VRP with Vehicle Breakdown – A variation

- Suppose that vehicles are loaded with orders for specific customers that cannot be substituted.
- Each vehicle can only visit its own set of customers after leaving the depot
- The broken down vehicle must be visited by any other vehicle to pick up any items for delivery to its customers

Formulation issues

- Additional constraints
- Care with capacity constraints (pick-up and delivery)
- What is the maximum number of visits to the broken down vehicle?

2 active vehicles
1 broken vehicle
7 customers
each vehicle's starting position is different



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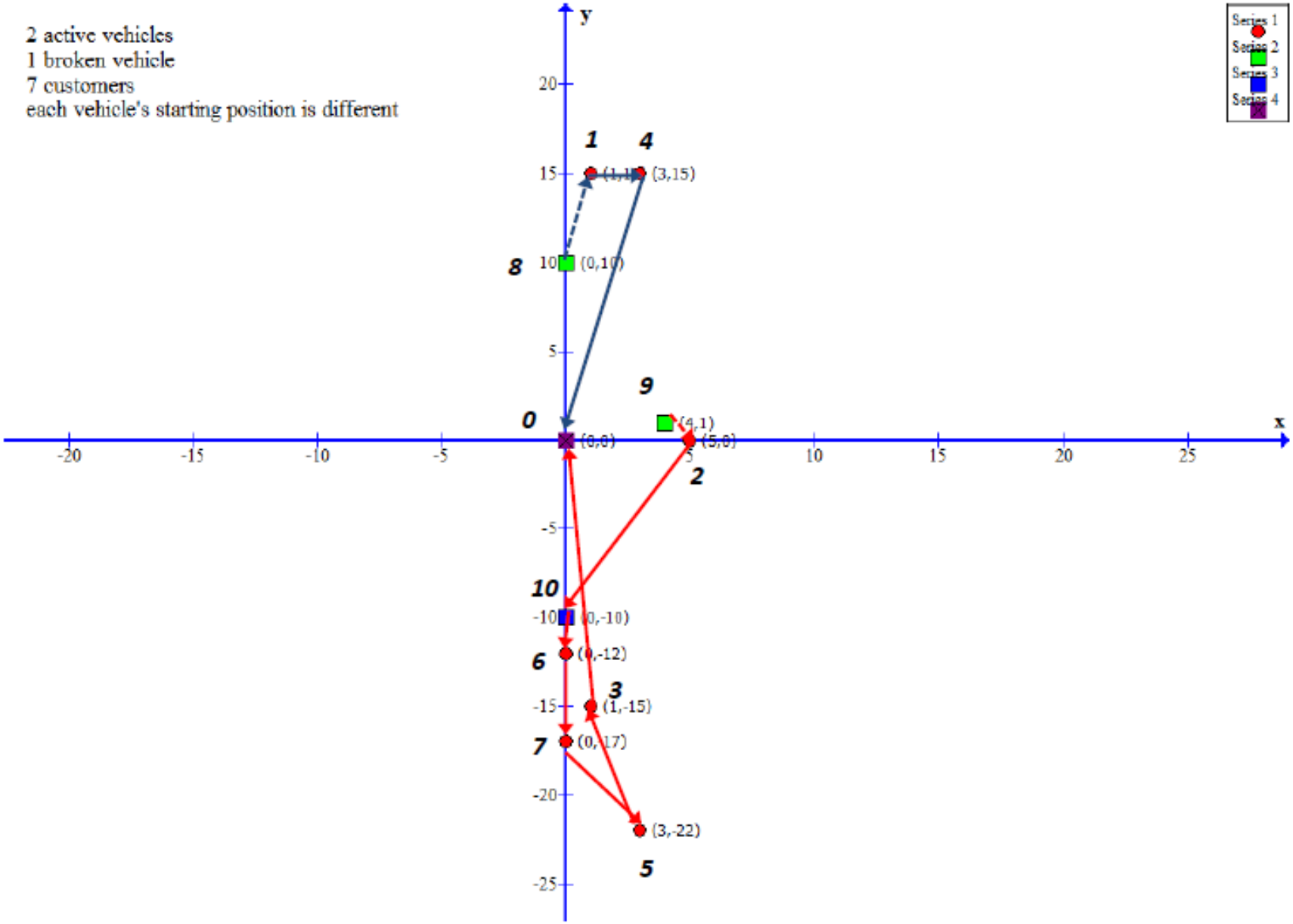
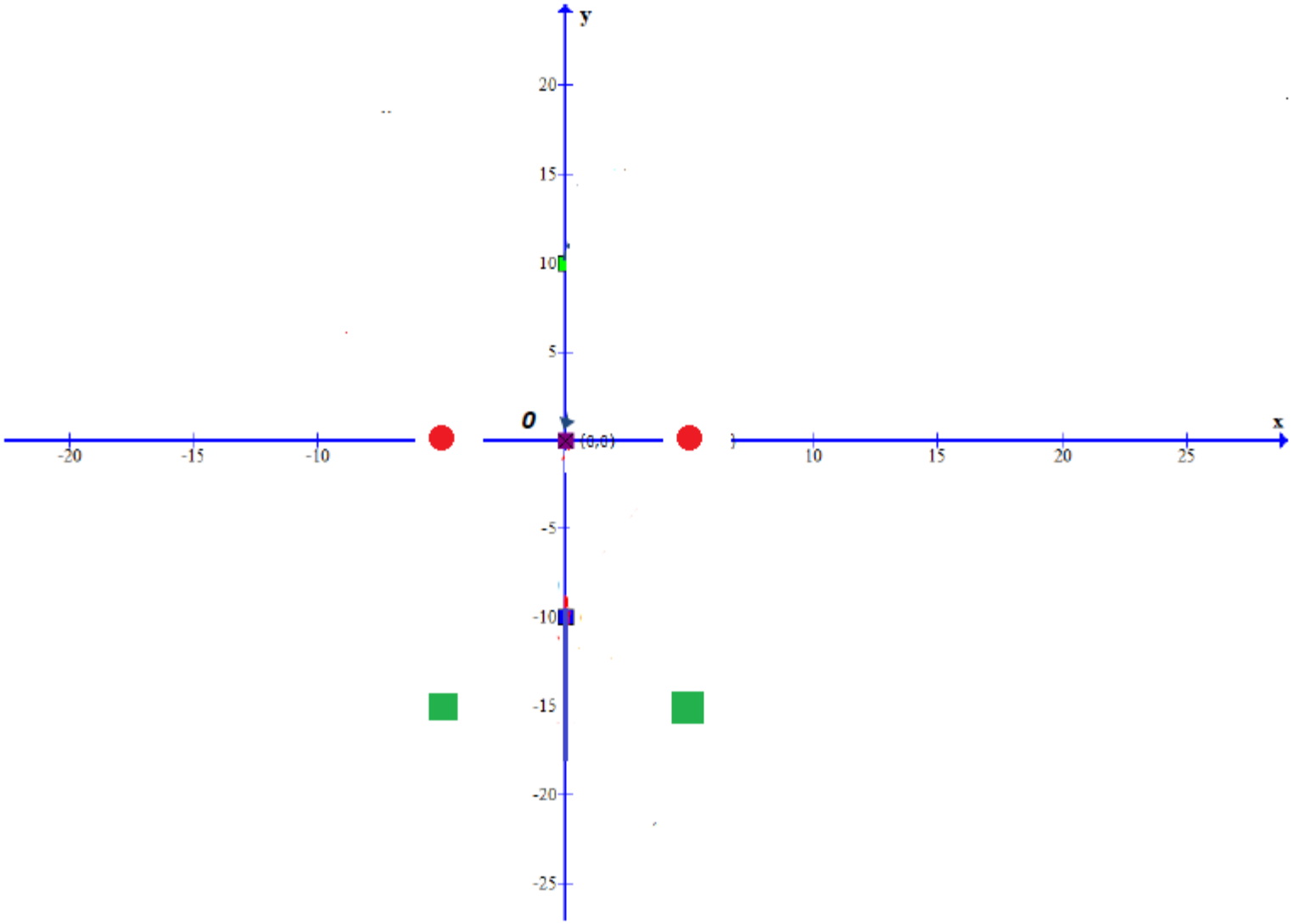
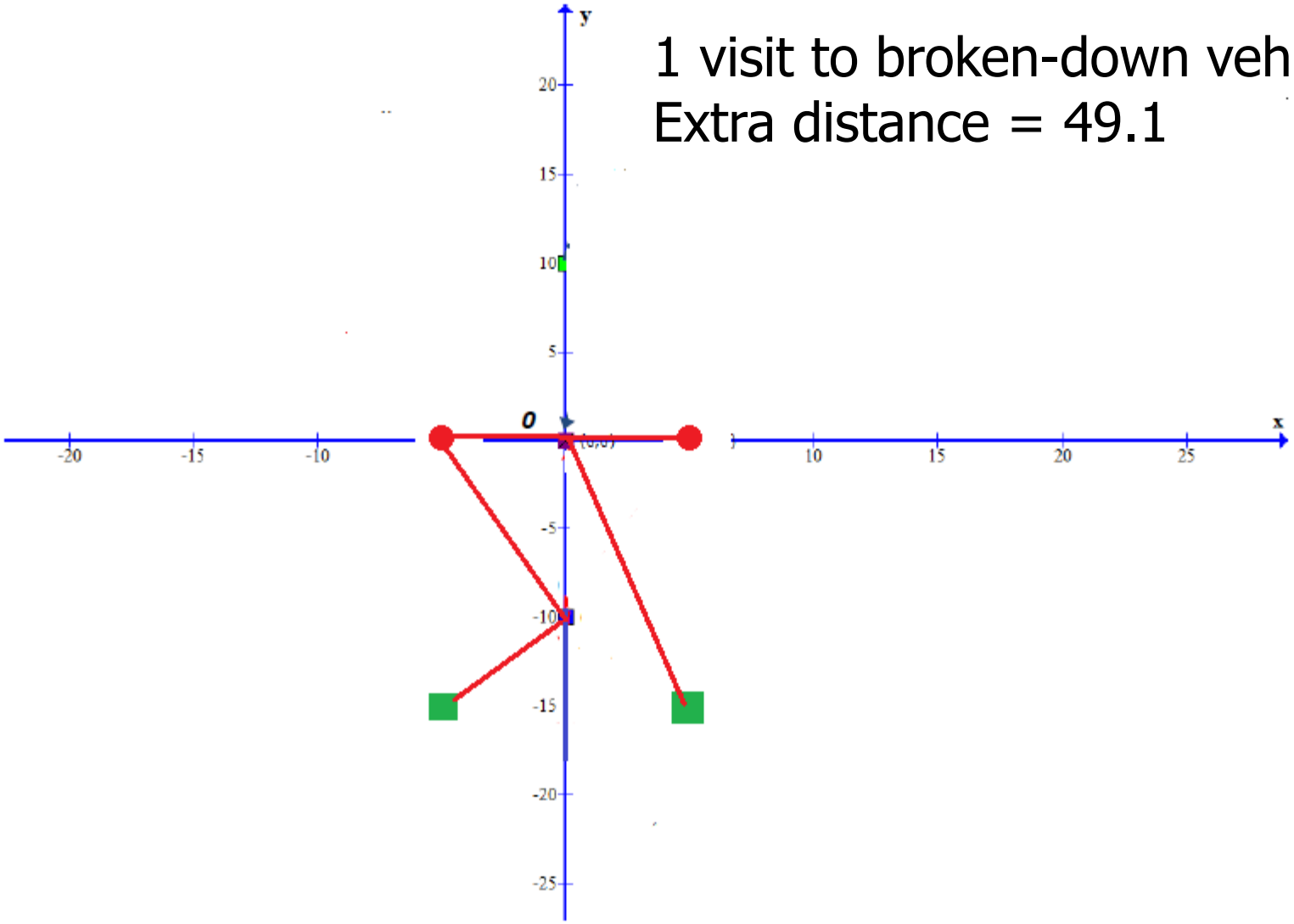


Example

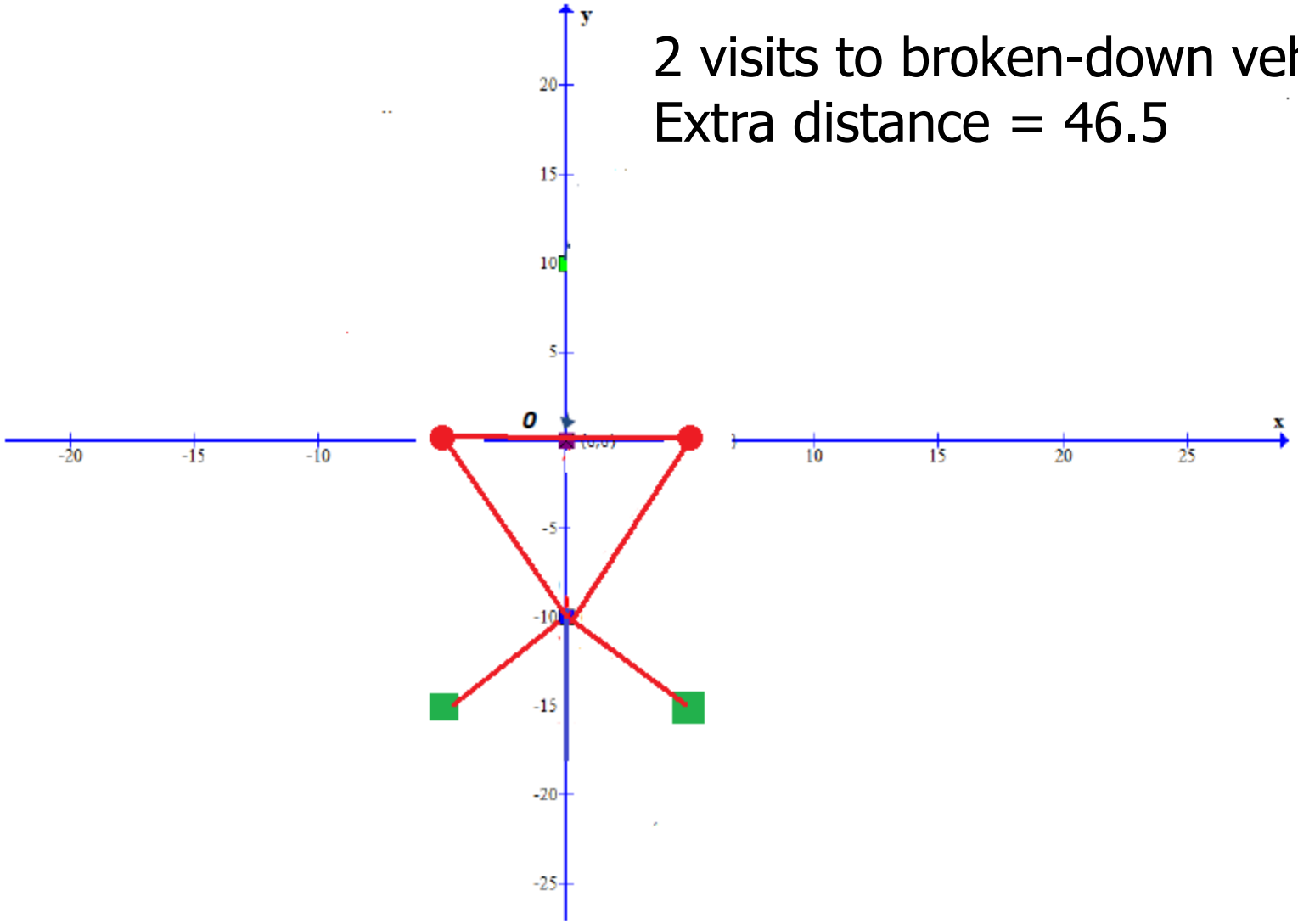


Example



1 visit to broken-down vehicle
Extra distance = 49.1

Example



2 visits to broken-down vehicle
Extra distance = 46.5

Other formulation issues

- Current formulation allows for different capacities for the vehicles
- Also makes use of variables representing the time a vehicle arrives at a customer
  - This means that approach can be extended to problems involving objectives and constraints on time windows
- Plan is to test what size of problems can be reliably solved by the exact approach

Finally

- A heuristic approach, tested in a real case, is described in:
  - Minis I., Mamasis K and Zeimpekis V. (2012) Real-time management of vehicle breakdowns in urban freight distribution. Journal of Heuristics, Vol. 18 (3), pp 375-400.
- More details of our exact approach will be presented at VeRoLog:
  - Zambirinis S. and Eglese R. (2014) The disrupted vehicle routing problem with vehicle breakdown. Working paper. To be presented at VeRoLog 2014, Oslo, Norway 22-25 June 2014.

Questions ?

My questions

- What are important types of disruption to model in practice?
- What is the best way to take advantage from the solution to the undisrupted problem?
- Are there other (better) formulations for the last problem?