

Human solutions to the capacitated vehicle routing problem

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Overview

- Introduction
 - Human performance on visually presented problems
- The cVRP
- Experiments
 - Human solutions to cVRPs
 - Practice & hints
- Participant strategies
- Conclusions

Human problem-solving & visual problems

- Search heuristics versus perceptual recognition (Newell & Simon, 1972)
- TSP performance
 - Perceptual mechanism (MacGregor & Ormerod, 1996; Ormerod & Chronicle, 1999; MacGregor et al, 2000)
 - Heuristic search mechanism (van Rooj, Stege & Schactman, 2003; Lee & Vickers, 2000)
 - Hybrid mechanism (Graham, Joshi & Pizlo, 2000)

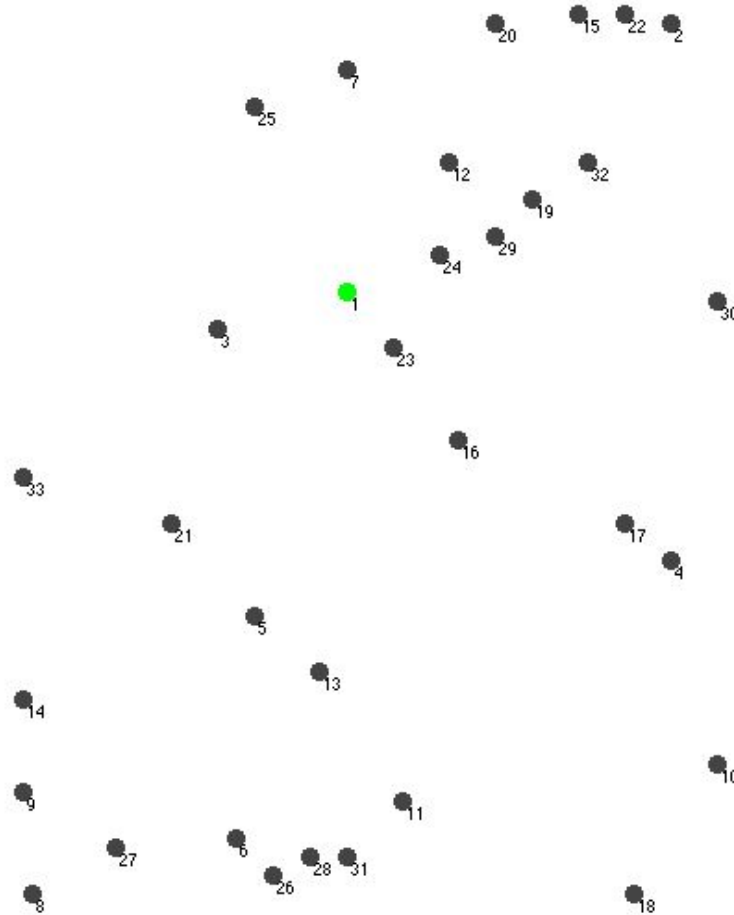
The cVRP

- Class of routing problems
 - <http://neo.lcc.uma.es/radi-aeb/WebVRP/>
 - VRP arises naturally in transportation, distribution and logistics [[Dantzing & Ramser 1959](#)].
- Given a set of customers with needs (loads) and vehicles (capacity limited) find the shortest set of tours from depot(s) that collect/deliver specified loads
- Intersection of TSP & Bin packing problems
- NP-hard

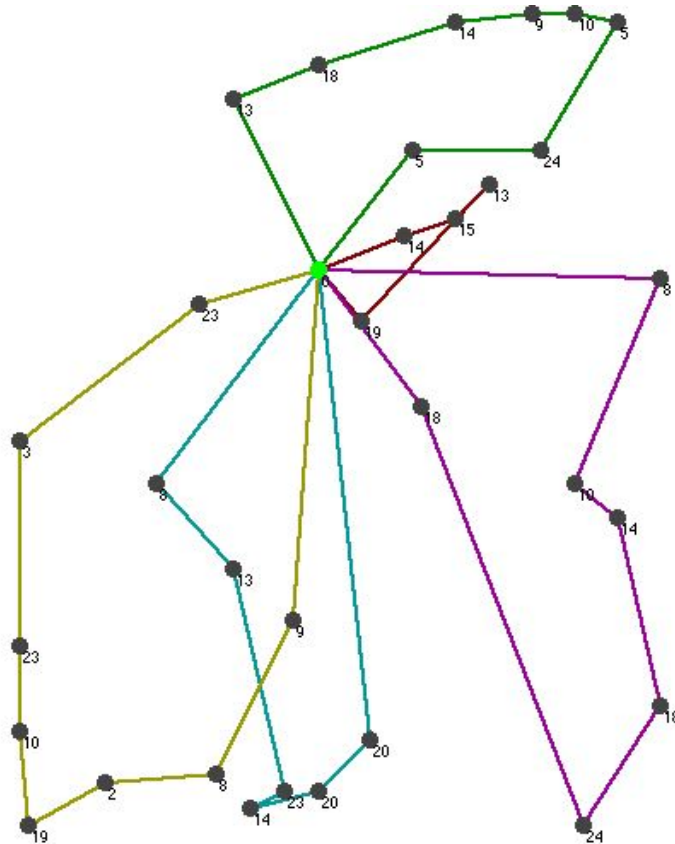
Example

(33 nodes, 5 trucks, 100 limit, 446 load total, mean=89 per truck – Augerat et al, 1972)

problem A



Optimum solution



File name: A-n33-k5.txt, dots: 33, routes:5, total distance (about): 675

VRP types (from VRP web site)

- Every vehicle has a limited capacity (Capacitated VRP - [CVRP](#))
- Every customer has to be supplied within a certain time window (VRP with time windows - [VRPTW](#))
- The vendor uses many depots to supply the customers (Multiple Depot VRP - [MDVRP](#))
- Customers may return some goods to the depot (VRP with Pick-Up and Delivering - [VRPPD](#))
- Customers may be served by more than one vehicle (Split Delivery VRP - [SDVRP](#))
- Some values (like number of customers, their demands, serve time or travel time) are random (Stochastic VRP - [SVRP](#))
- The deliveries may be done in some days (Periodic VRP - [PVRP](#))

Computational methods

- Exact methods
 - (typical branch & bound performance is 5-15% above optimal for random node cVRPs of 25-50 nodes)
- Heuristics
 - Constructive methods
 - Multiple route improvement
 - Two phase (cluster first route second)
- Metaheuristics
 - Ant algorithms, genetic algorithms, constraint programming, deterministic/simulated annealing, Tabu search

Issues

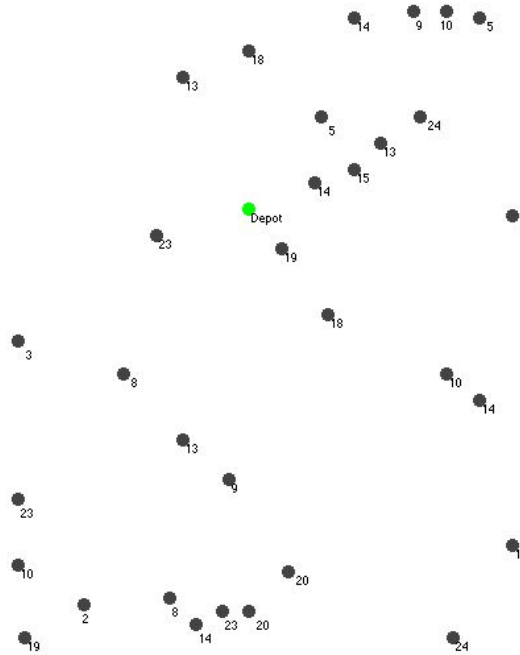
- Comparative human performance – is ‘competence’ restricted to eTSPs?
 - Environmental limitations of optimal solving (cf. Gigerenzer’s fast & frugal heuristics)
- What kinds of strategies might human participants apply?
 - Strategic differences across individuals
 - Strategic differences across problems
- Choosing between computational methods – can human strategies help inform this decision?

Ex.1 problem characteristics

- Problem size
 - 33 vs. 39 nodes
- Routes
 - 5 vs. 6
- (Capacity parameterisation)
 - 89 to 95 mean loads
- (Visual node patterns/distribution)

N33-k5

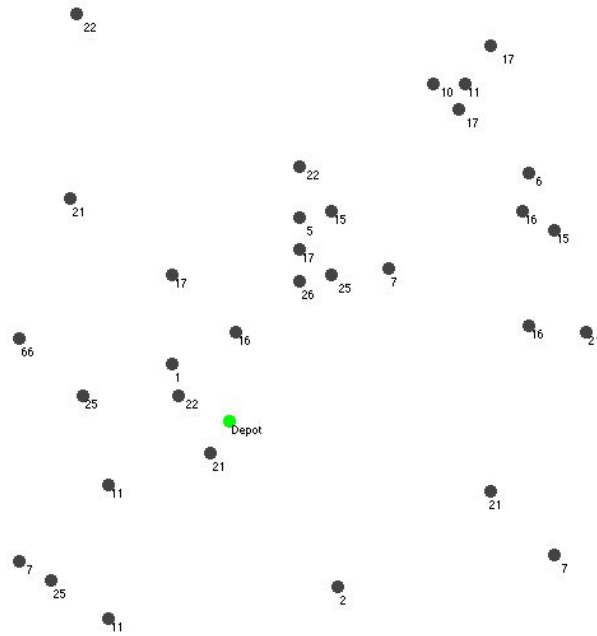
A1



For this problem, you have five trucks. There is a total of 446 units to collect, averaging 89 per truck. Draw five routes that visit each and every one of the sites starting from the depot (the green dot), making sure that each truck returns to the depot with no more than 100 units on board. When you finish, remember to colour each truck route, and write the number of the truck (from 1 to 5) next to the route.

N33-k6

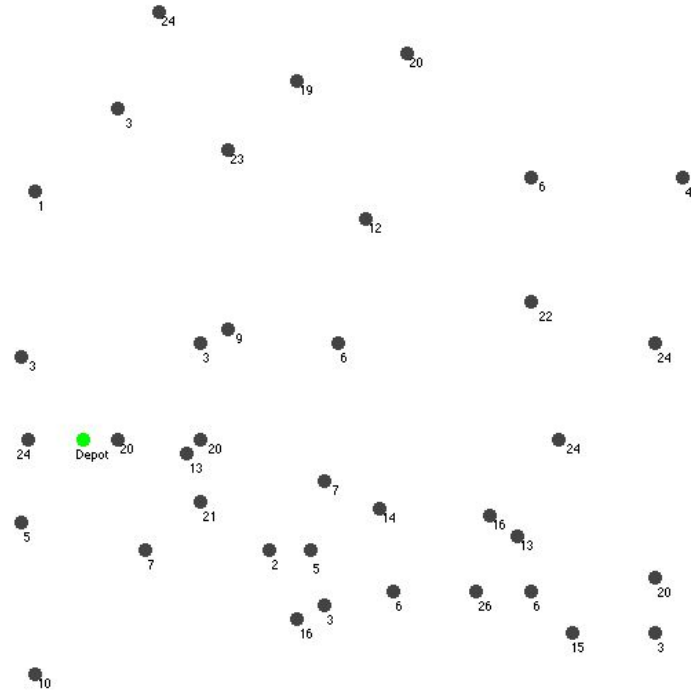
B1



For this problem, you have six trucks. There is a total of 541 units to collect, averaging 90 per truck. Draw six routes that visit each and every one of the sites starting from the depot (the green dot), making sure that each truck returns to the depot with no more than 100 units on board. When you finish, remember to colour each truck route, and write the number of the truck (from 1 to 6) next to the route.

N39-k5

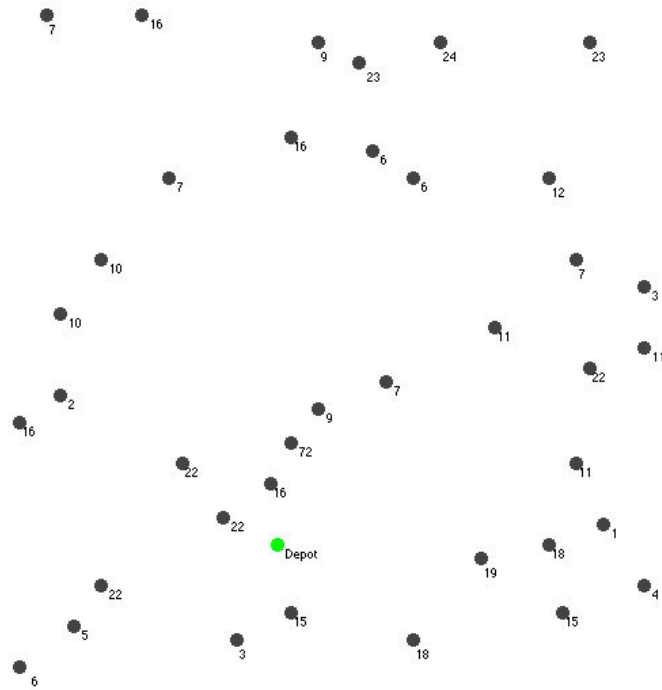
C1



For this problem, you have five trucks. There is a total of 475 units to collect, averaging 95 per truck. Draw five routes that visit each and every one of the sites starting from the depot (the green dot), making sure that each truck returns to the depot with no more than 100 units on board. When you finish, remember to colour each truck route, and write the number of the truck (from 1 to 5) next to the route.

N39-k6

D1



For this problem, you have six trucks. There is a total of 526 units to collect, averaging 88 per truck. Draw six routes that visit each and every one of the sites starting from the depot (the green dot), making sure that each truck returns to the depot with no more than 100 units on board. When you finish, remember to colour each truck route, and write the number of the truck (from 1 to 6) next to the route.

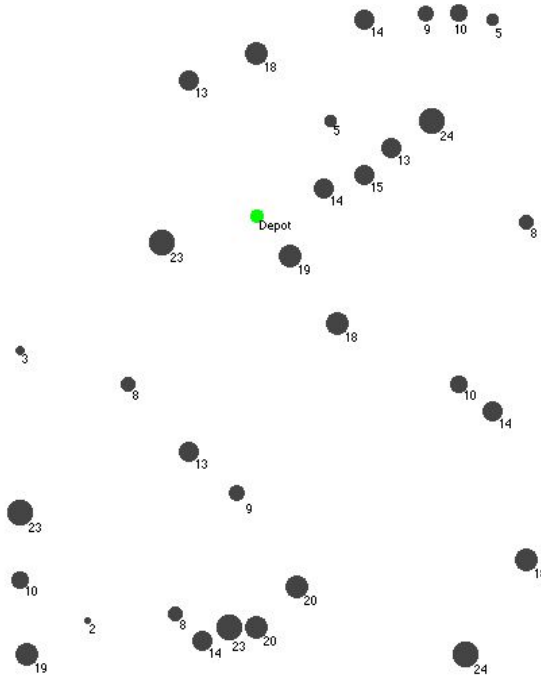
Ex. 1 Design

- Within Ss
 - Size (33 vs. 39)
 - Routes (5 vs. 6)
- Between Ss
 - Equal vs. sized nodes

Load proportional nodes ($2 * \sqrt{\text{load}}$)

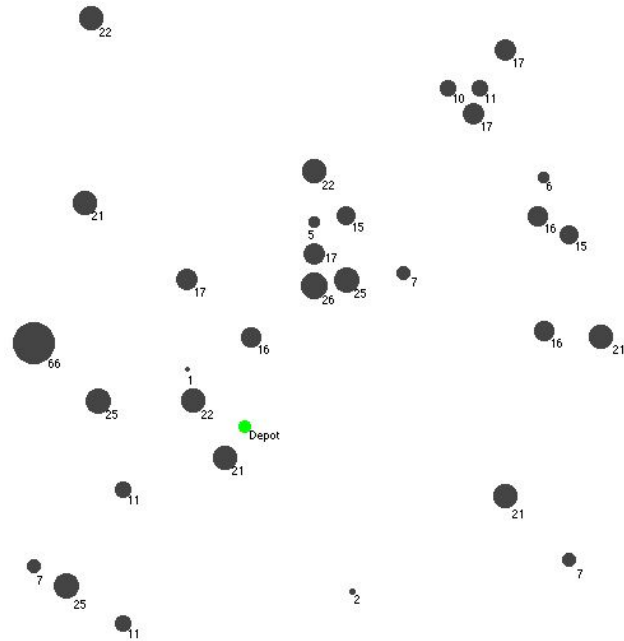
(possible effects – increased clustering, large load precedence, Pragnanz enhancement/disruption)

A2



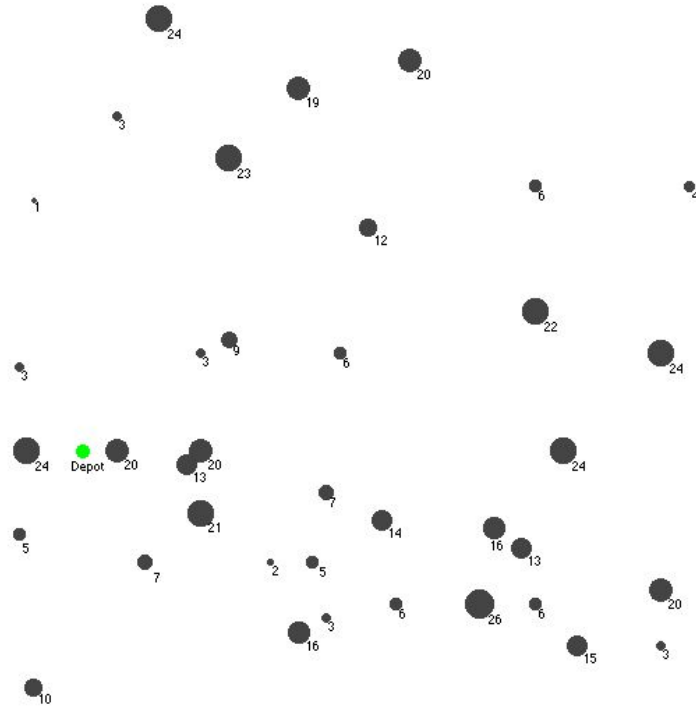
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B2



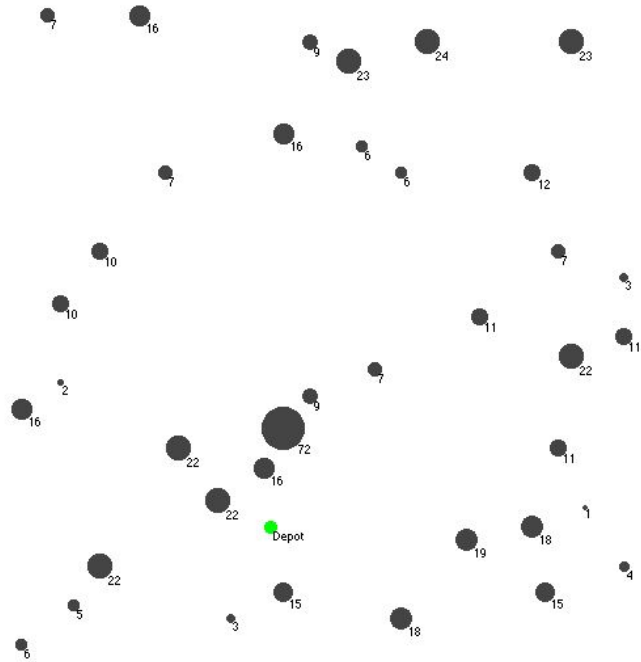
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D2



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Ex 1 Method

- Participants
 - 48 adults (31 UG & PG students - paid, 17 post-education -volunteer),
 - Age range 18-65, mean 32.5 years
- Self-paced
 - Range 12-50 mins, mean 23.5 mins (6 mins per problem)
- Pencil-drawn solutions on paper
 - routes subsequently coloured

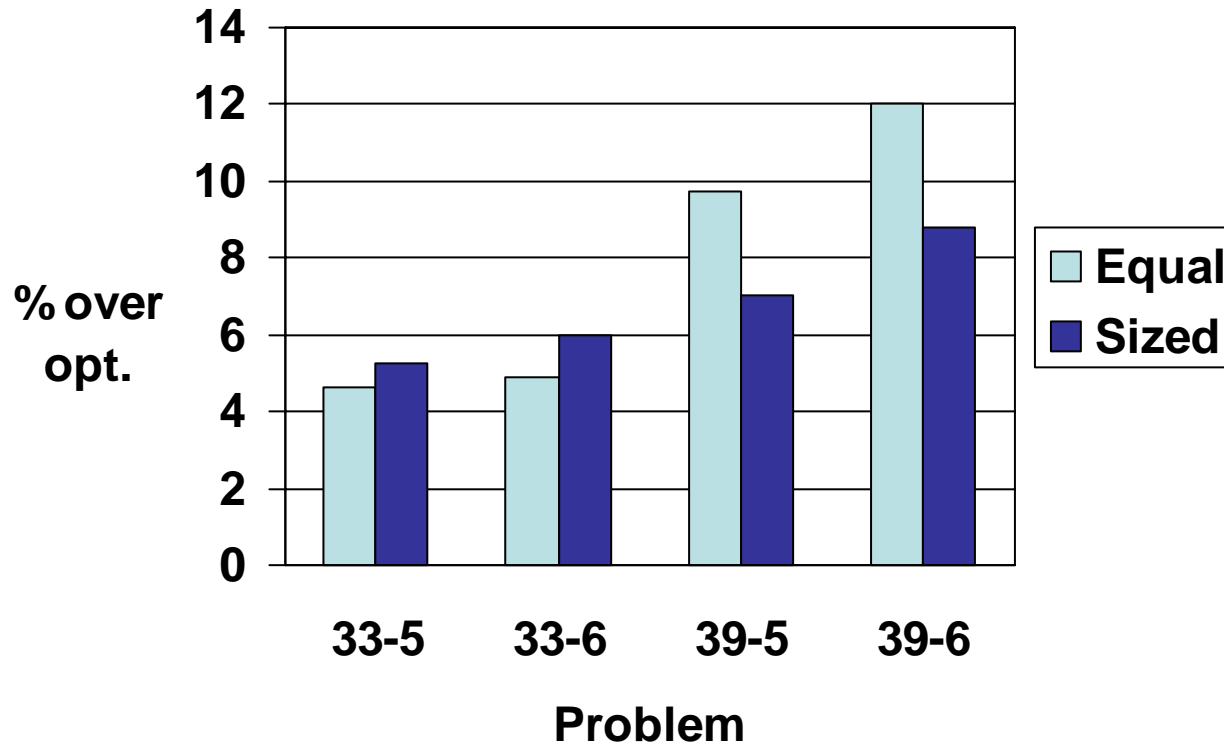
Participant instructions

- ...Your task is to plan the routes for each truck, aiming to *minimise the total distance* travelled by the trucks in visiting all the sites...
- Remember
 1. Use all, but no more than, the allowed number of trucks.
 2. Do not exceed the 100 unit capacity of any one truck.
 3. Return to the depot after drawing the route for each truck.
 4. Number the routes to show the order in which you produced them.
 5. Make sure you visit every site to complete the problem.
 6. Aim to minimise the total distance travelled by the trucks for each problem.

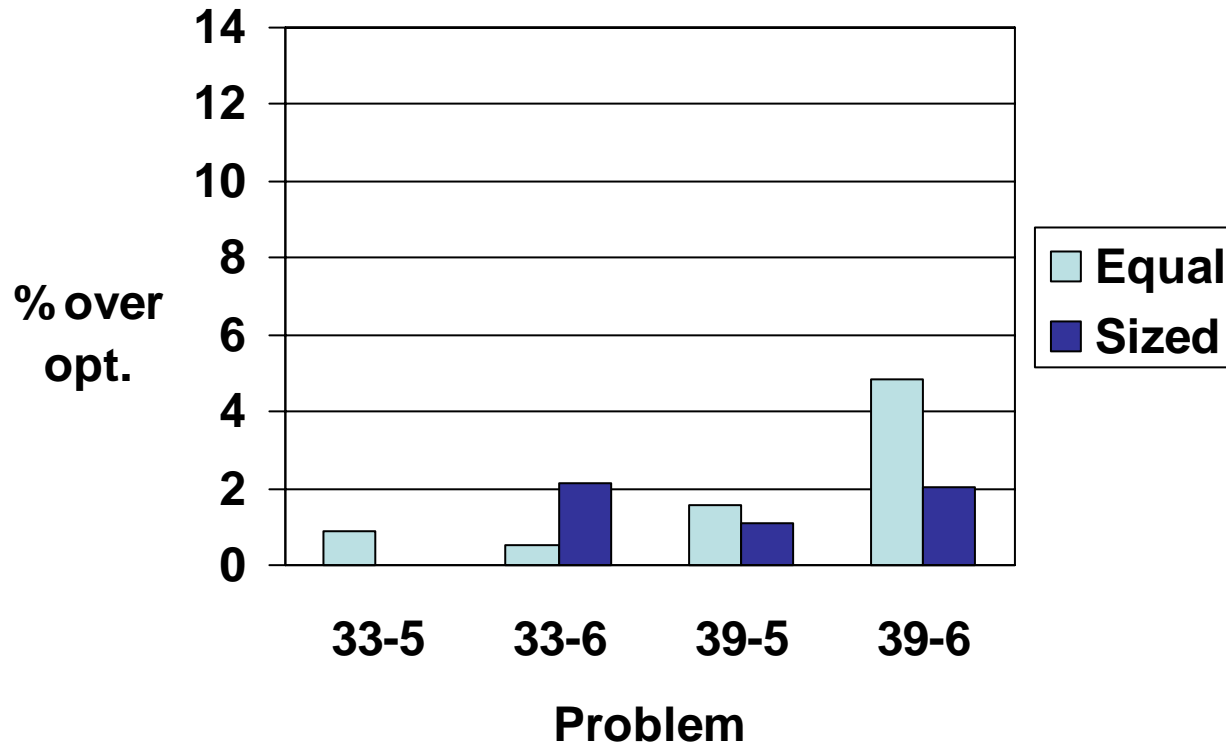
Instructions for each problem

“For this problem, you have *five* trucks. There is a total of *446* units to collect, averaging *89* per truck. Draw five routes that visit each and every one of the sites starting from the depot (the green dot), making sure that each truck returns to the depot with no more than 100 units on board. When you finish, remember to colour each truck route, and write the number of the truck (from 1 to 5) next to the route.”

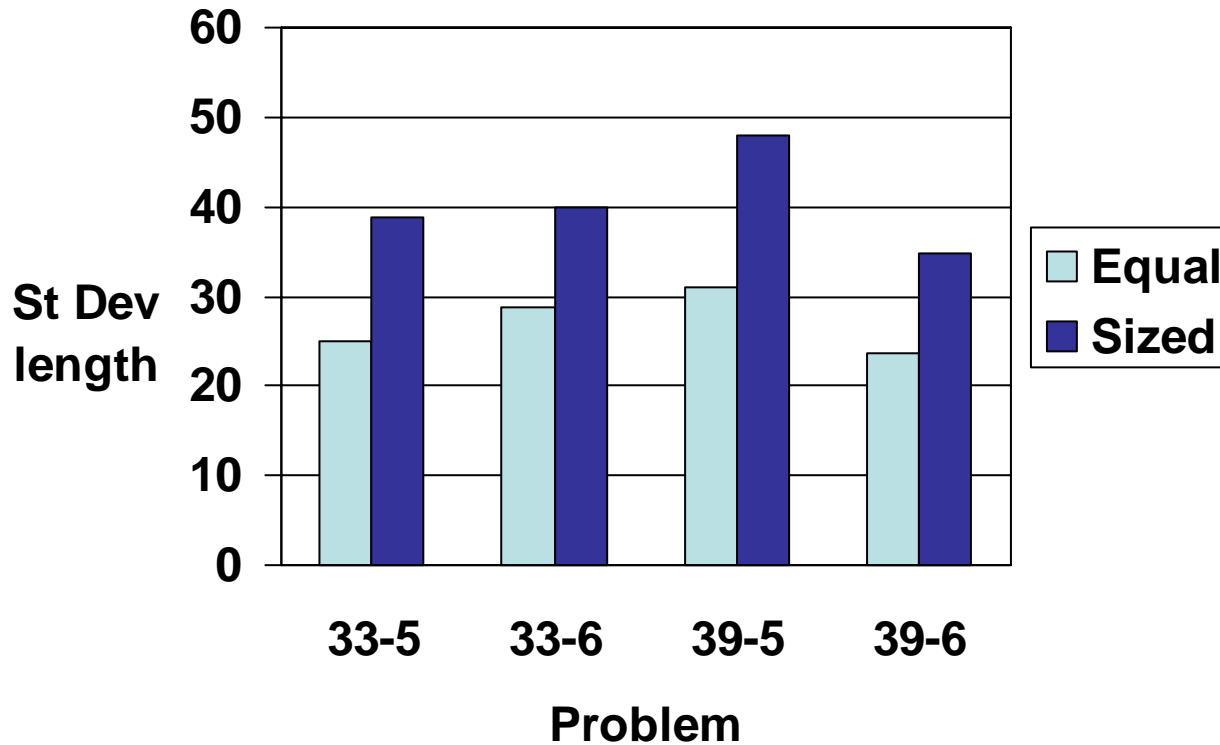
Ex. 1 Results: % over optimal



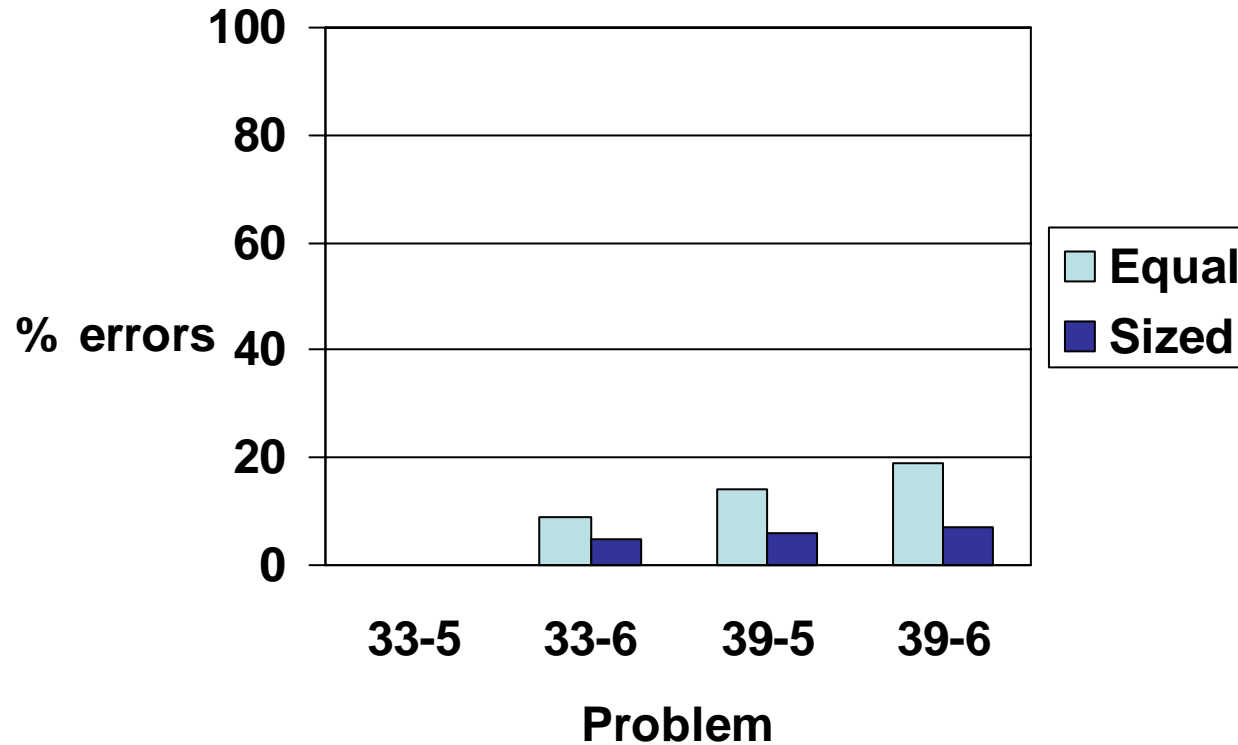
Ex. 1 Results: best solution



Ex. 1 Results: Standard deviations



Ex. 1 Results: % Errors



Ex 1 solution characteristics

- Few duplicate solutions across participants
- Routes tend to cross/overlap less than optimal tours
- Routes tend to exhibit 'Pragnanz'
 - Similar surface area, length, number of nodes
 - Lines follow continuations

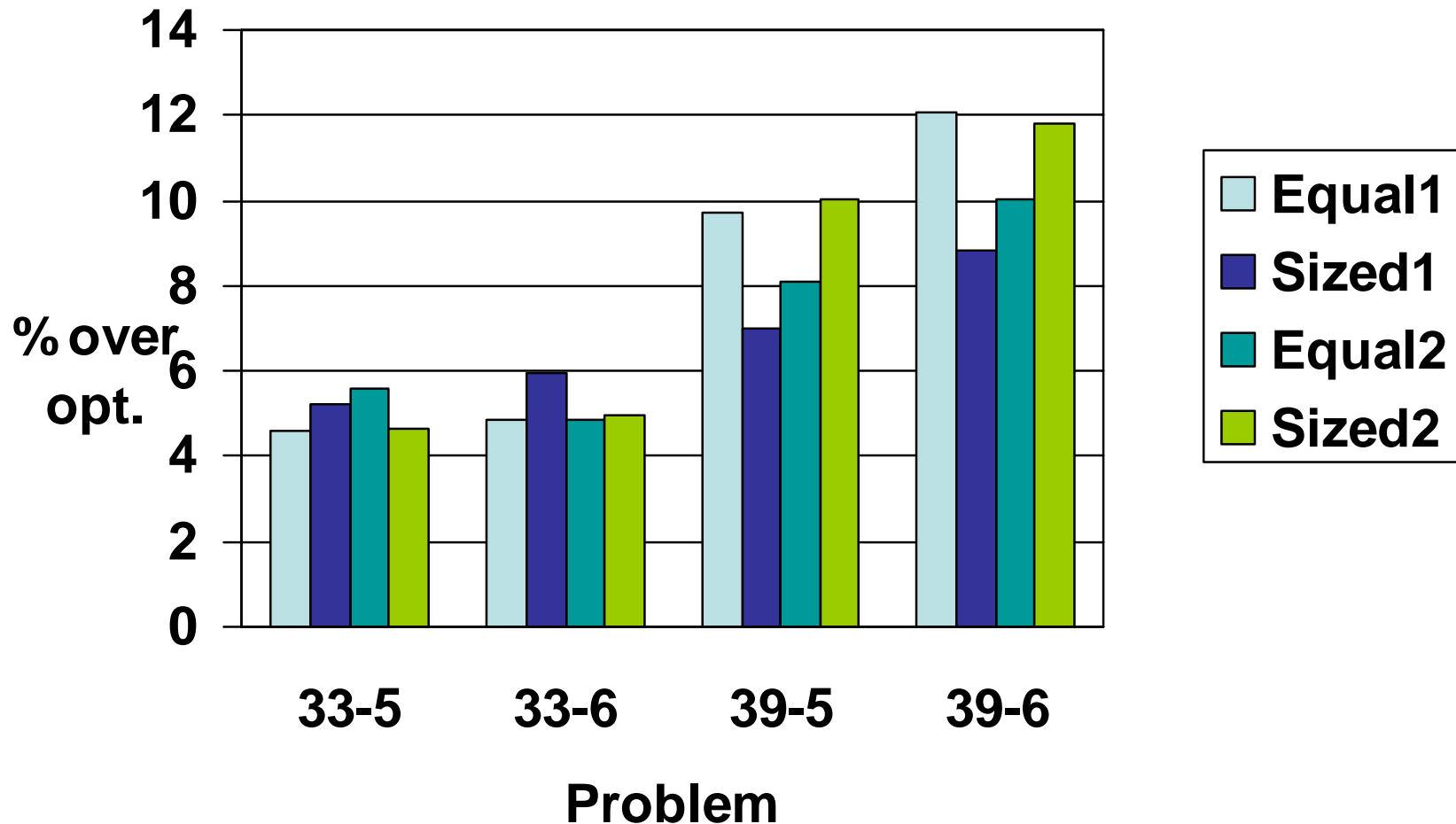
Ex 2: practice & instruction

- Task & problems – as Ex 1.
- Participants
 - 20 UG students
 - Age range 18-31, mean 23.1 years
- Instructions
 - Practice problem (23 node four trucks) + solution
 - Hints on solution characteristics

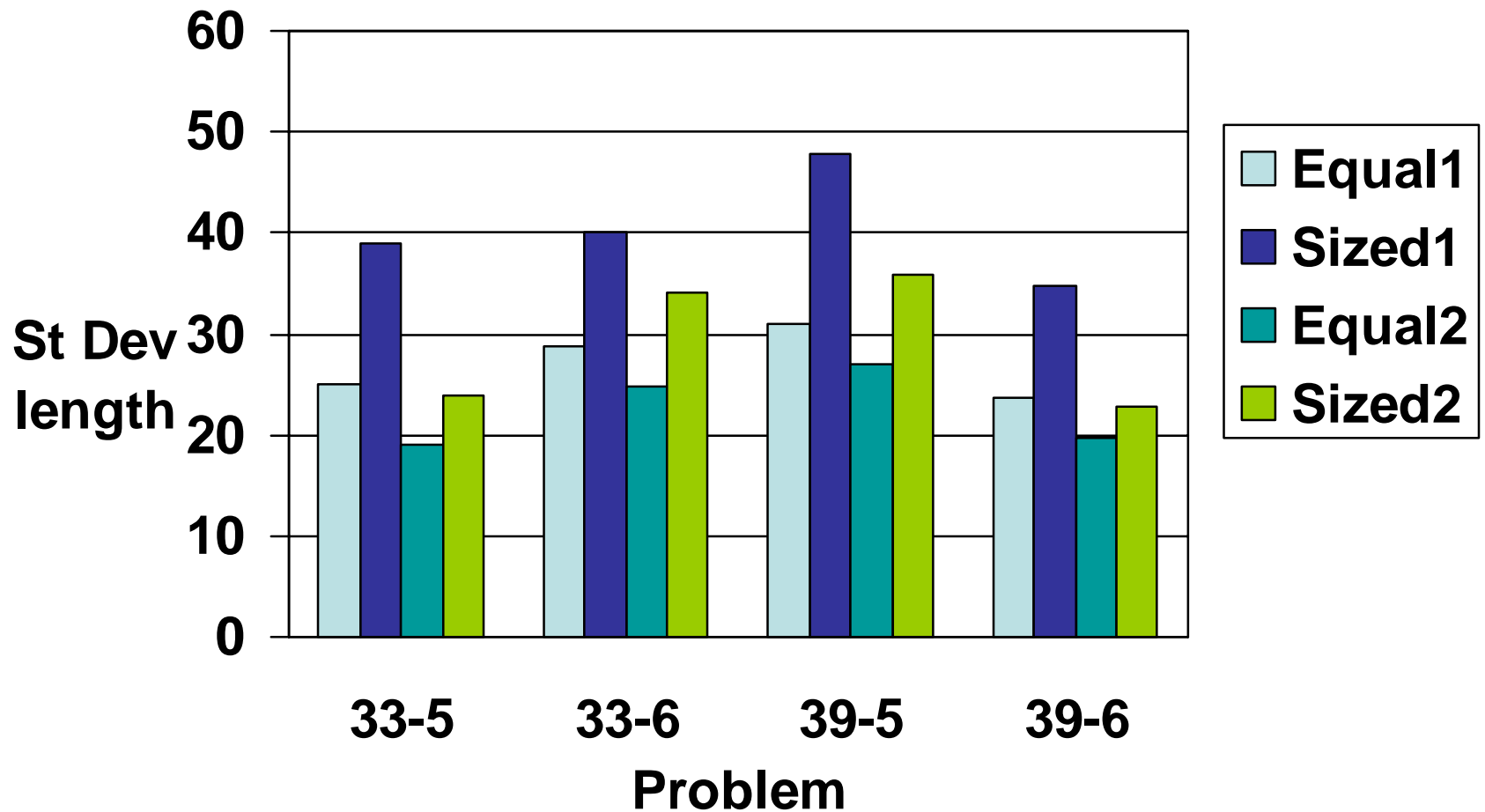
Ex 2 Hints

- Petal shape of routes
- Clusters, local & peripheral
- Line crossings and sharp angles
- Improving routes after production

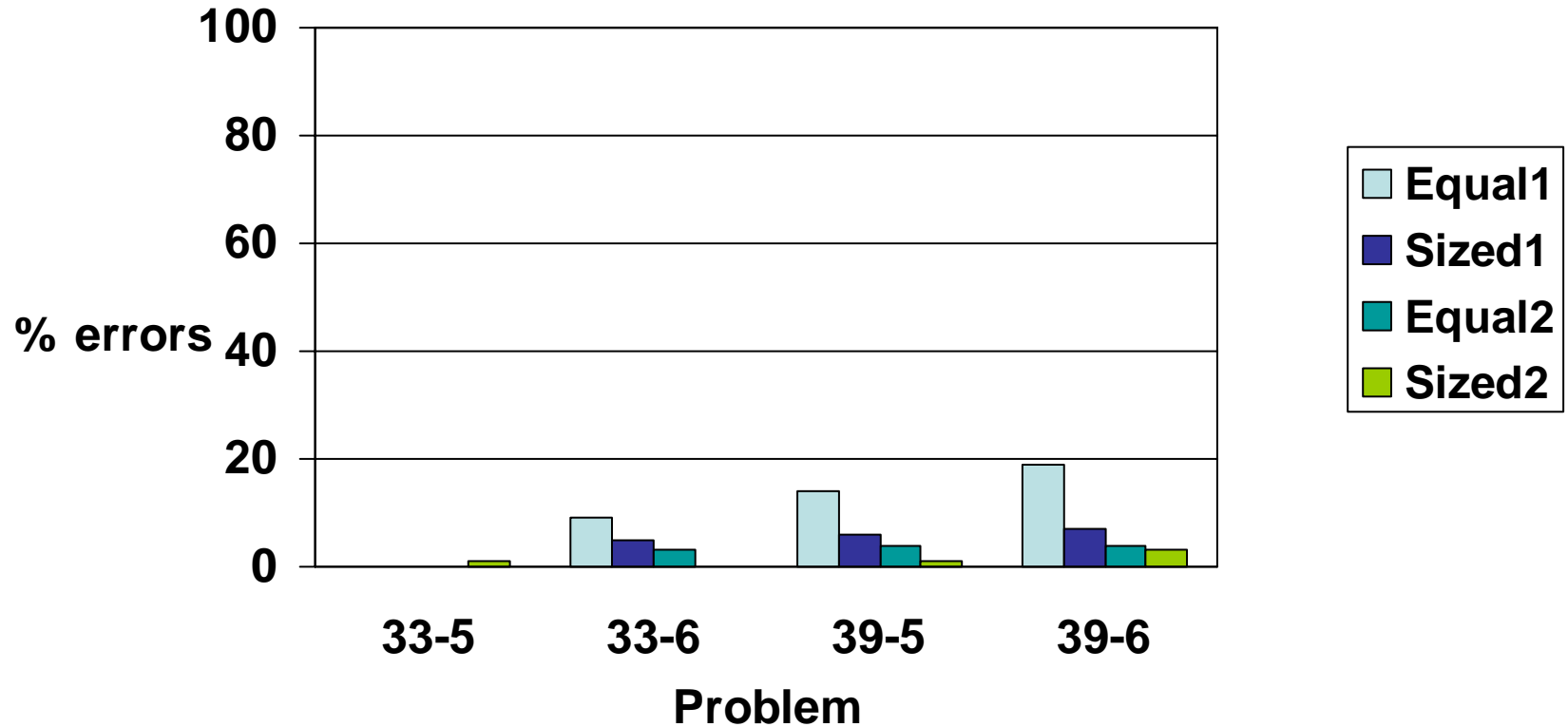
Ex. 2 Results: % over optimal



Ex. 2 Results: Standard deviations



Ex. 2 Results: % Errors



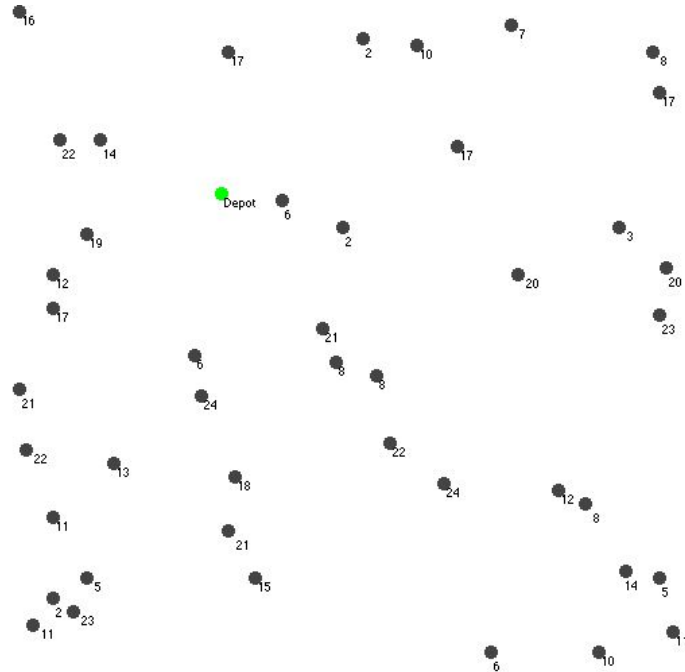
Summary of results

- Ex 1 (size vs. display)
 - Human performance on VRPs is of good quality
 - More route type variability than with TSPs
 - Less route length variability than with TSPs
 - Performance influenced by ‘counting’ requirement
 - Display characteristics affect performance
 - Pragnanz effects
 - Utilisation of node sizing with larger problems
 - Individual differences in utilisation of display
- Ex 2 (practice & hints)
 - enhance equal-node problems, impair sized-node problems (larger problems only)

Pilot study....!

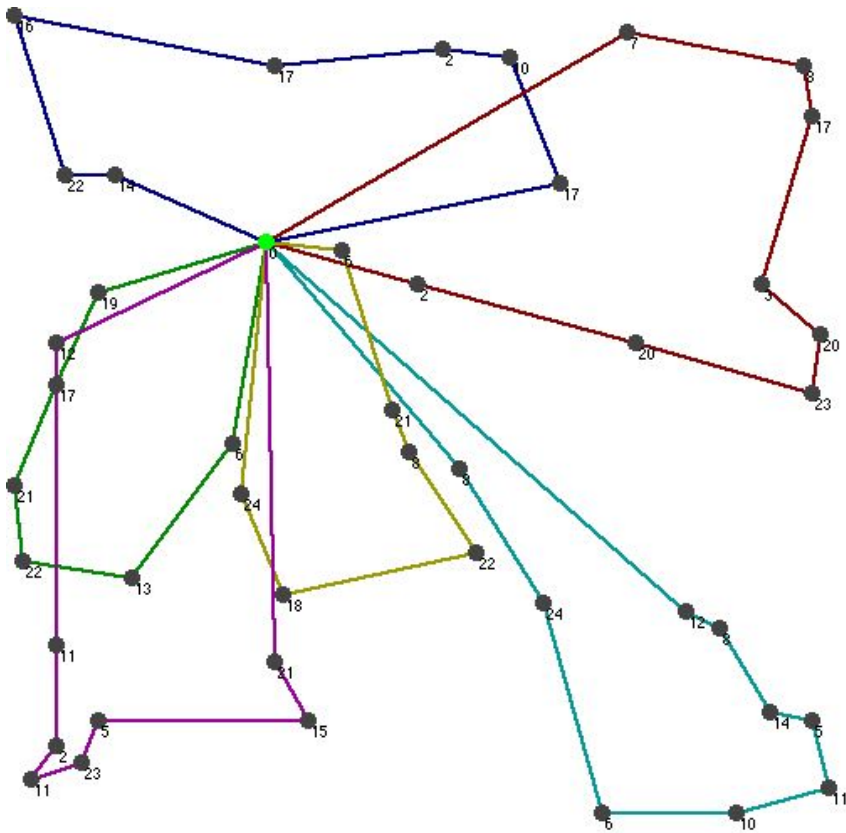
- Four participants
- Solved six problems including:
 - 54 node x 7 trucks (96 per truck)
 - 45 node x 6 trucks (99 per truck)

N45-6



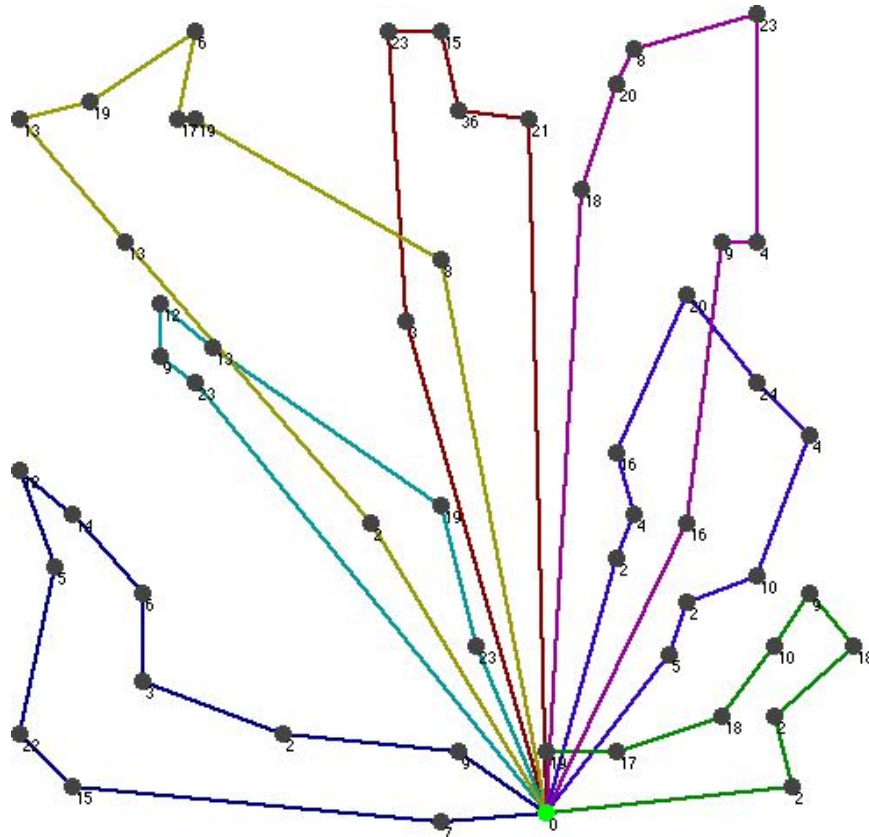
For this problem, you have six trucks. There is a total of 593 units to collect, averaging 99 per truck (i.e. nearly 100!) Draw six routes that visit each and every one of the sites starting from the depot (the green dot), making sure that each truck returns to the depot with no more than 100 units on board. Remember to change pen colour after drawing each truck route, and write the number of the truck (from 1 to 6) next to the route.

N45-6 optimal solution



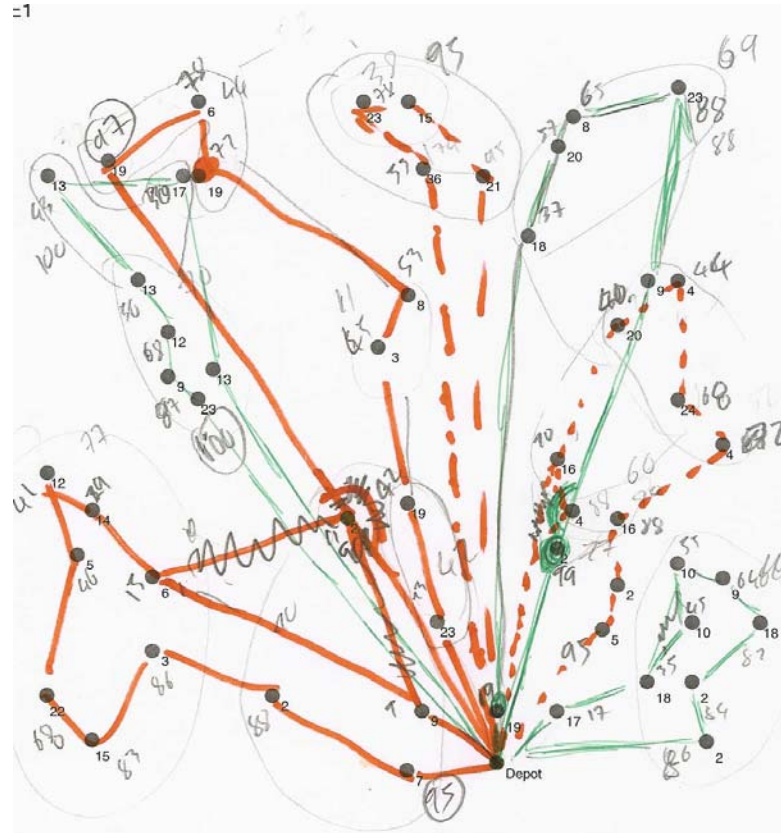
File name: A-n45-k6.txt, dots: 45, routes:6, total distance (about): 946

N54-7 solution



Participant example (2)

=1



For this problem, you have seven trucks. There is a total of 669 units to collect, averaging 96 per truck. Draw seven routes that visit each and every one of the sites starting from the depot (the green dot), making sure that each truck returns to the depot with no more than 100 units on board. Remember to change pen colour after drawing each truck route, and write the number of the truck (from 1 to 7) next to the route.

total = 1190

Pilot results

- 45 – 6 (99 mean)
 - 9.5% over optimum, best 3.4%
- 54-7 (96 mean)
 - 6.2% over optimum, best 2.4%

Participant strategies

- Effective
 - Cluster counting
 - Draw 'by eye' then refine by counting
 - Linear construction with tally
- Less effective
 - Balancing route properties
 - Aiming for maximum loads

Conclusions

- Human performance is impressive on a more general class of optimisation problems than TSP
- Some of this competence may come from the constraint imposed by the 'tally' requirement
- Some of this competence is underpinned by a range of strategies
- Interactions between perceptual and heuristic components of performance
- Instructional interventions can enhance or impair, depending on problem environment