Organization of the airline operation in El Dorado airport

- The operation of airline in El Dorado manages more than 10 different activities that are divides in 3 groups (a=international, b= household, c=other). According to their skills, agents can do just some kind of activities.
- The time of operation of airline is about 24h/7d. The program must do the planning horizon of one week that starts Tuesday at 0 am and finish on Wednesday at 5:30 am.
- The planning horizon has 8 days. From Tuesday 0 am to Wednesday at 6 am the planning horizon is divided in 396 periods of 30 minutes, where the first period of each day is [00:00 to 00:30] and the last period of day is [23:30 to 00:00]. For example, the period [10:00 at 10:30] refers to the lapse where agent works from 10:00 (inclusive) to 10:30 (not inclusive).
- During a turn, agents can be assigned as at least one activity and maximum four activities (a, b or c).
- Airline subcontract external company´s services to assure transport to agents who start o finish their job without public transport (period from 21:00 to 09:00 am). The agent must go in just one vehicle o could share with other agents if they are beginning or finishing their job at same time. (Decision of sharing depends on the applicative that you should program)

Shift organization

- Duration of one turn is exactly of 9 hours and is composed by 4 phases.
    - Phase 1 has a term of 2 hours
    - Phase 2 has a term of 2:30 hours
    - Phase 3 has a term of 2:30 hours
    - Phase 4 has a term of 2 hours
- Each phase has an assigned skill of work in an activity of agent. During this phase, the agents can just work in assigned activity. Is possible that one agent has the same skill in more than one phase.
- Each turn has a feeding break. This break has a term of 1 hour exactly. The time of start is predetermined and depends on time of the beginning of turn

Demand of agents in airport

- Each activity has a demand that is expressed by the number of required agents in each period of 30 minutes, For example if the demand of the period that starts at 22:00 is 10, means that is necessary 10 agents to do this activity between 10:00 pm and 10:30 pm.
- As far as possible, all demand can be attended. If in a given period the number of available agents is smaller than necessary demand, the difference results in "Demand unattended"

Planning of working days and free days of agents.

- There are 74 available agents to contract in airport
- If an agent works one day, must be assigned a turn, on the contrary must be assigned a freed day. Cannot assign one agent more than one turn per day.

- Free days and holidays for agents was the result of a previous decision of the company, these days are preset.
- If there are not contracted agents during days of week, the program must assign in break time
- Must be contract at least 30 agents

Turns definition

- Turns are determined to each working day of agents. The term of turn refers to the time of the beginning of work, at this time must be assigned the skills that agents will need in each of the four phases of turn. Feeding break time is preset by the beginning hour of turn.
- For example, the turn 06:30-cbba has the following characteristics:
    - Start time of turn 06:30 am (end of turn after 9 hours, that means at 3:30pm)
    - During this turn, agent do the following activities:
        - Phase 1: activity (c) from 6:30am to 8:30am
        - Phase 2: activity (b) from 8:30 to 11am
        - Phase 3: activity (b) from 11am to 13:30
        - Phase 4: activity (a) from 13:30 to 15:30
    - Start time of feeding break: 13:00, time of end of feeding 14:00. Remember that this information is already defined for each turn.

Turn's restrictions

- The number of worked hours while a turn is 8 hours +1 hour of feeding break, in total 9 hours.
- An agent must have at least 12 hours of rest between the end of turn and the begging of new one.
- When agent has a free day assigned, is necessary 24 hours between the end of the last turn and the beginning on new one

Feeding's break restrictions

- During a break agent cannot attend any demand
- The term of a break is 1 hour exactly
- Start time of break is preset and depends on start time of turn

Skill's restrictions

- Is defined for each agent a binary parameter that determine if it has the skill to do some activity (have skill= 1, have not skill=0)
- One skill with score of 0 is forbidden. Thus, agent cannot have in one turn an assigned skill in which their score is 0.

Definitions according to agent's transport

- The route of a vehicle refers to all the journey, from start point to end point. In case of the journey is just for pick up from the addresses, start point of route will be the location of the first passenger and the end point of route will be airport. On the contrary if the journey is just to carry agents to their addresses, start point will be in airport and the end point will be the location of the last passenger leaved in his address. Both cases there is not back to start point (route is no a circuit).

- Labor journey is a measurement of route of vehicle por each agent, from their address to airport (if is a pickup route) or from airport to their addresses (if is a leaving route). For example, there are 3 passengers in a vehicle, will be a route and 3 journeys (one per passenger).
- An agent has a direct journey when is the first to arrive to their house (or is the last to collect if is a route to the airport). The journey is called indirect when agent must wait to other passengers arrive to their addresses (or wait to other passengers will be collected to arrive to airport). If the journey of agent is indirect, is assumed that will have to wait more time than a direct journey
- A passenger that is alone in a vehicle has mandatory a direct journey
- Additional kilometers of indirect journey will be the difference between the distance of the direct journey and distance of the indirect journey for the same agent.

Transport restrictions

- If an agent starts or finish their turn between [21:00 – 6:30], must be assigned a vehicle
- In a period one vehicle just can collect passengers or leave passengers. Cannot do both activities. One vehicle can do more than one journey in a period.
- I there are mor than one agent who has finished their work in a given period (or start their turn in a given period), program can make that agents share vehicle (this is a decision of applicative).
- Just can share vehicle:
    - Passengers that have the same kind of journey: airport to home or home to airport, cannot assign the same vehicle to the passenger that goes to work and other passenger that goes to home.
    - Passengers that start (or finish) their work at same period. For example, cannot have in a vehicle a passenger that starts (or finish) his turn at 8 pm and other at 8:30 pm
- There is not limit in the number of available vehicles per period. However, for practical reasons, this value is limited to 52 vehicle per period. If it necessary to use more vehicles, teacher must be consulted.
- Your program just must manage the decision to assign a vehicle to passengers that start (o finish) at same time. I assumed that transport's company select optimal hours to pick up passengers in order to everybody arrives to airport in the moment which turn starts.
- Your applicative must determinate in each period and por each vehicle which agents have to be assigned and their order. If the route is airport-home, passenger in first position in vehicle will have a direct journey and the other an indirect journey. If the route is home- airport, the last passenger will have a direct journey and the other indirect journeys
- Distance between home of agents and airport is input.
- To evaluate dispersion of locations of agents addresses and airport, coordinates are input (although can help, there is not mandatory to use this information to optimize) The coordinates of airport are (0,0)

Application decisions

- Determine which agents will be contracted
- Build turns for each agent for each day (just start time, because the end of turn and break and determined by start time)
- Define assigned skill in each of four phases of turn.

Main optimization criterion:

Airline takes into account two main criteria of planning, which are presented above and in order of priority:

1. Customer service: Minimize unattended demand.
2. Wellness of agents: minimize dissatisfaction of agents because of be assigned in indirect journeys without penalize the efficiency in the use of vehicles. Actually, there are 1,83 people/ vehicle (because could be possible to remove every indirect journeys just assign 1 agent per vehicle, but this will low the efficiency of the use of vehicles)

Secondary optimization criterion

Are included secondary criteria of planning that must be contemplate when cannot find more ways to improve the main criteria. In order of priority

1. Wellness of agents: minimize variability in start hours in turn of each agent
2. Transportation cost: minimize the number of routes done by the transports company (cost of airline)
3. Wellness of agents: assign more free days to agents than airline preassign.

Objective function that wanted to be optimized considers this criteria y priorities:

FO missing demand: Minimize missing demand

As far as possible, demand will be satisfied. That means that in each period there is enough agents to serve. However, due to limited human resources, is not possible to guarantee that in each period of week, there are more agents than demand. This criterion penalizes the number of all missing demand on one side and the other side the number of missing demands per period during the week.

$$OFUnattended = \sum_{d=1}^{7}\sum_{p=0}^{23} Un_{d,p} + 25 \times \max_{\substack{d=1..7 \\ p=0..23}} (Un_{d,p})$$

$$Un_{d,p} = Max(0, Dem_{d,p,night} - \sum_{h \epsilon abilities} N_{d,p,h})$$

$\boldsymbol{Un_{d,p}}$: The number of agents missing to satisfy the total demand in period p on day d.

$\boldsymbol{Dem_{d,p}}$: The demand of agents required in period p of day d.

$\boldsymbol{N_{d,p,h}}$: The number of agents assigned to meet the demand for activity h during the period p on day d.

Minimize additional kilometers in each journey without harming efficiency in use of vehicles.

Seek to minimize the number of kilometers of passengers who has indirect journeys (Do not leave fist or do not collect last). This FO has two components:

- Frist component evaluate la ratio between average of additional kilometers per indirect journey and the ideal average distance if every journey was direct.
- Second component generates a penalization if the efficiency in use of vehicle is less than the current

: Ideal distance that would have a Passenger t if has a direct journey

: Difference between real traveled distance by passenger and distance that would have if it was a direct journey.

NInddirect: Number of indirect journeys (reminder: if there are 4 passengers in a vehicle, Will have 1 direct journey and 3 indirect journeys)

N: Number of indirect and direct journeys

NRoutes: number of used vehicles

E: Efficiency, average number of passengers per vehicle

: current efficiency = 1.83

FOVariability: Minimize variability in start hours

This FO allows to evaluate how much variability has start hours of an agent during the week. As far as possible will be assigned schedules for agents that will not change a lot during the week

Number of days that agents works per week

Start time assigned to agent *a* the day *d* (time is expressed in hours. For example, start at 7:30 is 7.5)

$$\boldsymbol{Min\ Z} = 10000 \times (OFUnattended + OFWellness) + OFVariability + NRoutes$$

$$OFVariability = \sum_{a \in Agents} Var(a)$$

$$Var(a) = \begin{cases} \sum_{\substack{d=1 \\ if\ agent\ a\ works\ on\ day\ d}}^{7} \left| Hstart_{a,d} - PromStart_a \right| & if\ agent\ a\ is\ hired \\ 0 & On\ the\ contrary \end{cases}$$

$$PromStart_a = \sum_{\substack{d=1 \\ if\ agent\ a\ works\ on\ day\ d}}^{7} \frac{HStart_{a,d}}{NDaysWorked_a}$$

$\boldsymbol{OFUnattended}$: The objective function of the Customer Service Supervisor which analyzes the results obtained on the demand that has been attended during the week.

$\boldsymbol{OFWellness}$: The objective function of the Transport Supervisor which analyzes the allocation of vehicles to the agents who need transportation during the week.

$\boldsymbol{NdaysWorked_a}$: The number of days the agent a works in the week.

$\boldsymbol{Hstart_{a,d}}$: Start time of the shift assigned to the agent a on day d.

$\boldsymbol{NRoutes}$: Number of vehicles transported.

$$OFWellness = \frac{\frac{\sum_{t \epsilon IndRoutes} kmExtraIndirect_t}{NIndirect}}{\frac{\sum_{t \epsilon Routes} IdealKm_t}{N}}$$

$$E = \frac{N}{NRoutes}$$

$\boldsymbol{IdealKm_t}$: The ideal distance a passenger would have if they had a direct route.
$\boldsymbol{kmExtraIndirect_t}$: Difference between the actual distance traveled by the passenger and the ideal distance if the agent had a direct route.
$\boldsymbol{NIndirect}$: Number of indirect routes.
$\boldsymbol{N}$: Number of passengers carried.
$\boldsymbol{E}$: Efficiency, Average number of passengers per vehicle.

Vehicle allocation

- Each vehicle for each period has 4 positions of passengers
- It necessary to put ids of passengers who travel together in the order which they will down (or up is a journey to airport)
- If there are less than 4 passengers, unoccupied positions must be empty
- The cells corresponding to unused vehicles must be empty
- To distinguish return journeys to home from journeys to airport use the following convention:
    - Return journeys to home will get the id of passengers
    - Journeys to airport id will be negative
    - In both cases the order of id correspond to the order of get off (or get on) the vehicle.