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# OPTIMIZATION AND SIMULATION OF KIOSK CASH REPLENISHMENT

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## Background

54 kiosk in Kayseri

900 banknotes capacity

6 am-11 pm working hours

1 team collects money


## Problem Statement

Kiosks can signal at the same time

The team cannot catch all of them at the same time

The team has a lot of leisure time

## Current System

Customers load money from kiosks

The team receives signal if kiosk has 350 banknotes

The team take a way to the kiosk

Is there signal closer

The team altered its direction due to a new signal

The team continues the way

Money is collected from kiosks

## What is new?

New constraint alter time windows according to the service time of kiosks. In this time windows, the change in the number of customers by time is shown cumulatively and the increase in each time interval is considered as piecewise linear function. One example of the projection of time windows and intervals shown in below.

According to this graph equations for the first and second service times constructed as;

$$C_0 = \frac{t_0 - t_1}{t_2 - t_1}, \; C_1 = \frac{t_0 - t_1}{t_2 - t_1}$$

Constraint 16 provide the next service time to be in these standardized intervals through the equation:

$$C_0 < C_1$$

These equations arrange service time continuously according to the previous service time of kiosk.

## Methodology

While the first constraint (1) provides the flow balance of the model, the next constraints (2), (3) ensure that the start and end point of the tours are the central knot. Constraints (4), (6) and (8) are time constraints and (5), (7), (9) prevented the team from waiting on the nodes.

In addition to this, the provision of service to the nodes starts before the earliest start time to the service and finish before the latest service time for the designated node (10). Starting and ending times of routes are (11) and (12). Restrictions (13) and (14) allow each kiosks to be visited within their own routes. Last constraint provides each route to start after the end of the previous route (15).

## Mathematical Model

$i, j$ represent kiosks

$k$ is the tour number

$N_0 = N \cup \{0\}$

### Parameters

$d_{ij}$ travelling time from $i$ to $j$

$e_{ik}$ earliest service time for kiosk $i$ in tour $k$

$u_{ik}$ latest service time for kiosk $i$ in tour $k$

si service time for i

$hm_i$ required number of tour for i

### Decision Variables

$AR_k$ Arrival time for route k to origin

$DE_k$ Departure time for route k from origin

$x_{ijk}$ 1 if kiosk $i$ served in tour $k$, 0 o.w.

$y_{ik}$ {1 if the team travelled $i$ to $j$ in tour $k$, 0 o.w.

$t_{ik}$ service start time at kiosk $i$ in route $k$

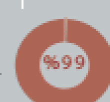
$C_{ik} = \frac{t_{ik} - t_{i1}}{t_{i2} - t_{i1}}$ standardized time windows of $i$ in route $k$

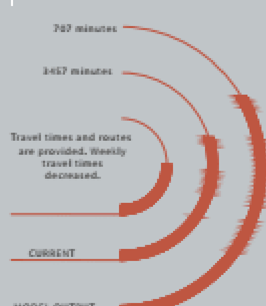
$$\min \sum d_{ij} * x_{ijk}$$

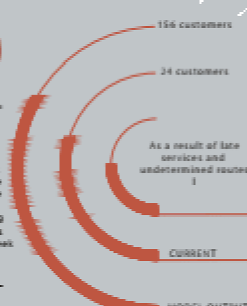
| | | |
|---|---|---|
| $\sum_i x_{ijk} - \sum_i x_{jik} = 0$ | $\forall j \in N_0, \forall k \in K$ | (1) |
| $\sum_i x_{0ik} \quad 1$ | $\forall k \in K$ | (2) |
| $\sum_{i \in N} x_{i0k} \quad 1$ | $\forall k \in K$ | (3) |
| $t_{ik} \quad d_{ij} \quad t_{jk} - \quad 1 - x_{ijk} \quad M < t_{jk}$ | $\forall (i, j) \in N \; \forall k \in K$ | (4) |
| $t_{ik} - d_{ij} - t_{jk} - \quad 1 - x_{ijk} \quad M < t_{jk}$ | $\forall (i, j) \in N \; \forall k \in K$ | (5) |
| $DE_k \quad d_{0i} - \quad 1 - x_{0ik} \quad M < t_{ik}$ | $\forall i \in N, \forall k \in K$ | (6) |
| $AR_k \quad d_{i0} - \quad 1 - x_{i0k} \quad M < t_{ik}$ | $\forall i \in N, \forall k \in K$ | (7) |
| $t_{ik} \quad d_{i0} - \quad 1 - x_{i0k} \quad M < AR_k$ | $\forall i \in N, \forall k \in K$ | (8) |
| $t_{ik} \quad d_{0i} - \quad 1 - x_{0ik} \quad M < DE_k$ | $\forall i \in N, \forall k \in K$ | (9) |
| $e_{ik} < t_{ik} < u_{ik}$ | $\forall i \in N_0, \forall k \in K$ | (10) |
| $e_{0k} < DE_k$ | $\forall k \in K$ | (11) |
| $AR_k < u_{0k}$ | $\forall k \in K$ | (12) |
| $\sum_j x_{ijk} \quad y_{ik}$ | $\forall i \in N, \forall k \in K$ | (13) |
| $y_{ik} \quad hm_i$ | $\forall i \in N, \forall k \in K$ | (14) |
| $AR_{k1} < DE_{k2}$ | $\forall k_1 < k_2$ | (15) |
| $C_{ik1} \quad 1 - y_{ik1} \quad M < C_{ik2} - \quad 1 - y_{ik2}$ | $M; \forall i \in N, \forall k_1 < k_2$ | (16) |
| $x_{ijk} \in \{0,1\}, \; y_{ik} \in \{0,1\}$ | | |

## Conclusion


The aim of this project is to decrease travel time for the team while decreasing the number of lost customer resulted by late services. GAMS and ARENA Simulation Software are used in this project. Mathematical model is solved in 3 hours. As a result of mathematical model and simulation %20 decrease in travel time is provided monthly. Customer lost decreased by %99. The team can catch all the customers without travelling too much between kiosks.

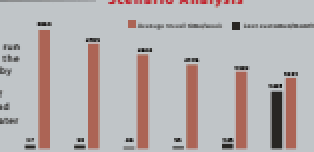



## Scenario Analysis

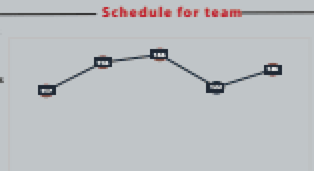
Different scenarios are run in Simulation by using the route that is provided by GAMS results. In these scenarios filling rate of kiosks are increased and the team takes a way later than before.



In these scenarios number of lost customer decreases until some point. But if the team continues to increase the earliest service time limit lost customer starting to increase. In all scenarios average travel time in a week decreases naturally.

## Schedule for team

Mathematical model is run to find an optimal travel time and routes for the team. Required service times for kiosks is given to the model that was provided by data analysing.



Maximum number of route is 5 for the most used kiosks. Route times and routes are given for one week. There are not too much differences of travel times between routes.

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