How society benefit from optimal vehicle routing pattern for Poultry Meat Distribution Network?

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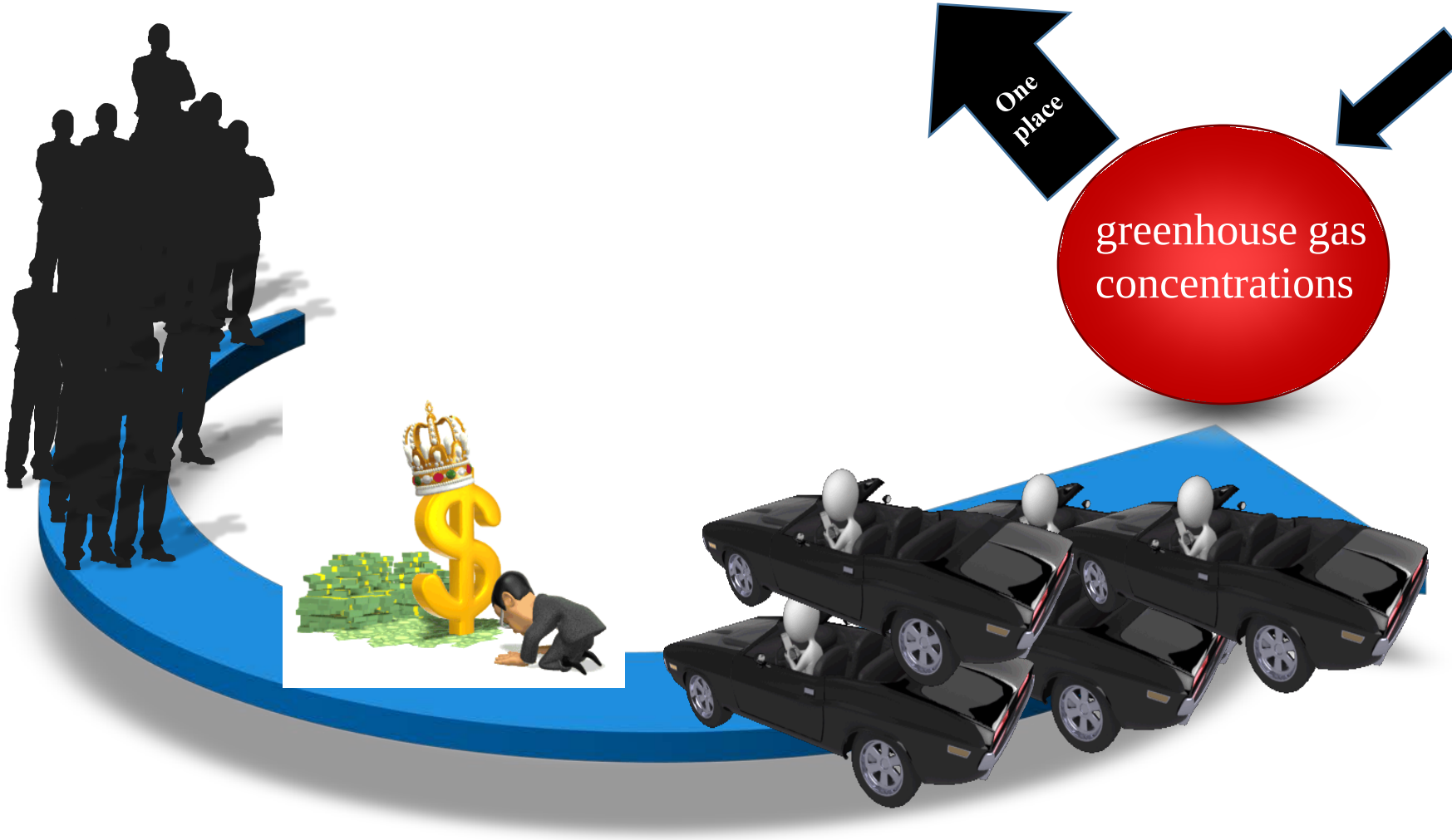
Tehran
most populous city in Iran with 8 million inhabitants
25th most populated city in the world

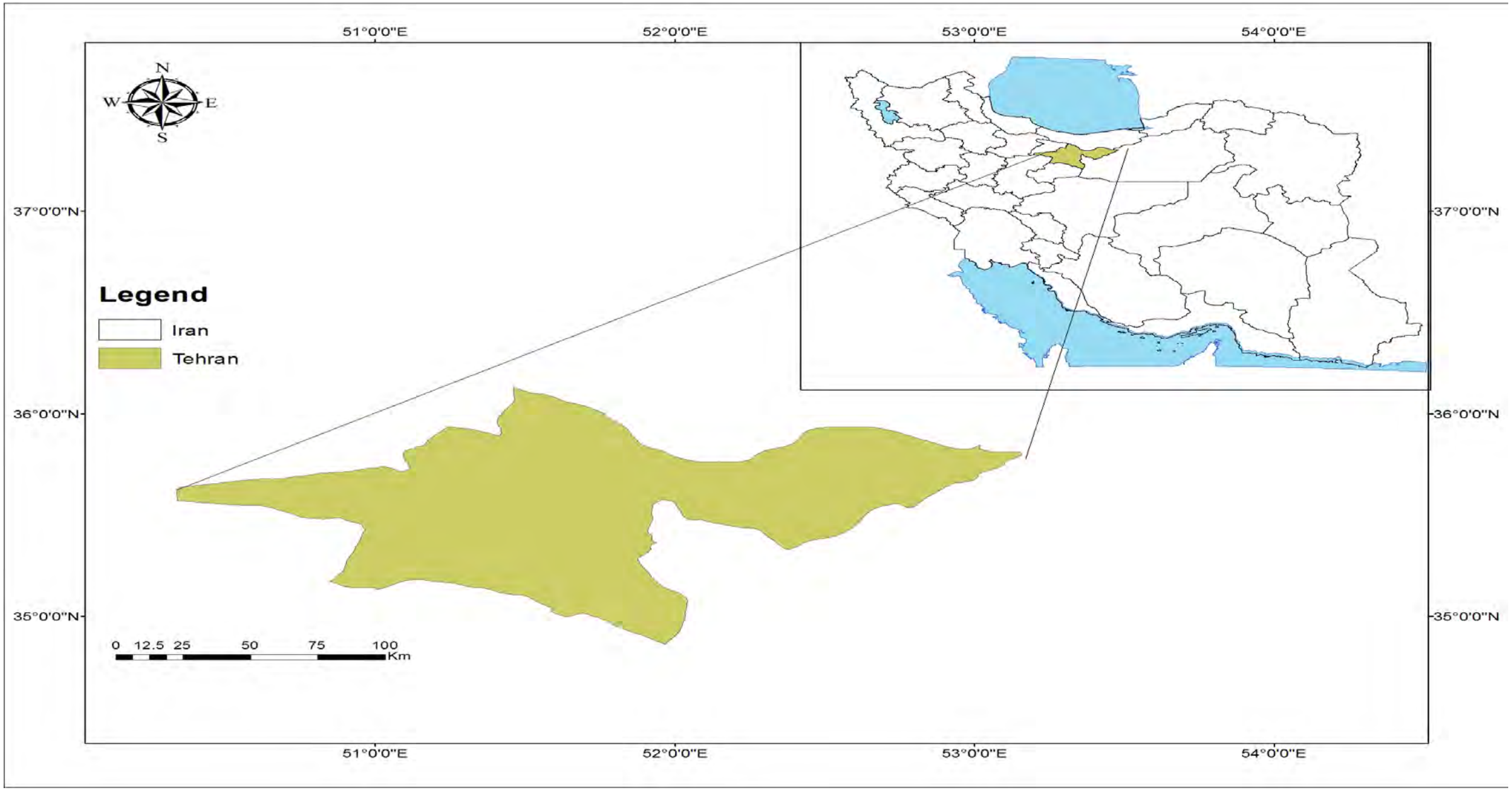


in developing countries

- Populations grow
- Income grow
- motor vehicle usage
- other economic changes

Increases demand for poultry

Study Area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Km

In the transport of perishable goods such as meat protein products, particularly poultry meat

1- food safety

2- quality along the supply chain

3- managing the costs of transportation

Approximately **18 percent** of the national income of Iran has been related to the transportation sector over the past decade with average growth of **12.3 percent annually**, making it one of the most important contributors to Iran's overall economic growth (Central Bank of Iran, 2012).

Tehran Municipality Management of fruit and vegetables Organization. (TMMFVO)

This is a governmental organization.

One of the goals of this organization is to managing the chicken meat distribution to 140 meat grocery in Tehran.

In Tehran, the whole chicken meat distribution conducting by Bahman and Piroozi central market squares, which is managing by (TMMFVO).

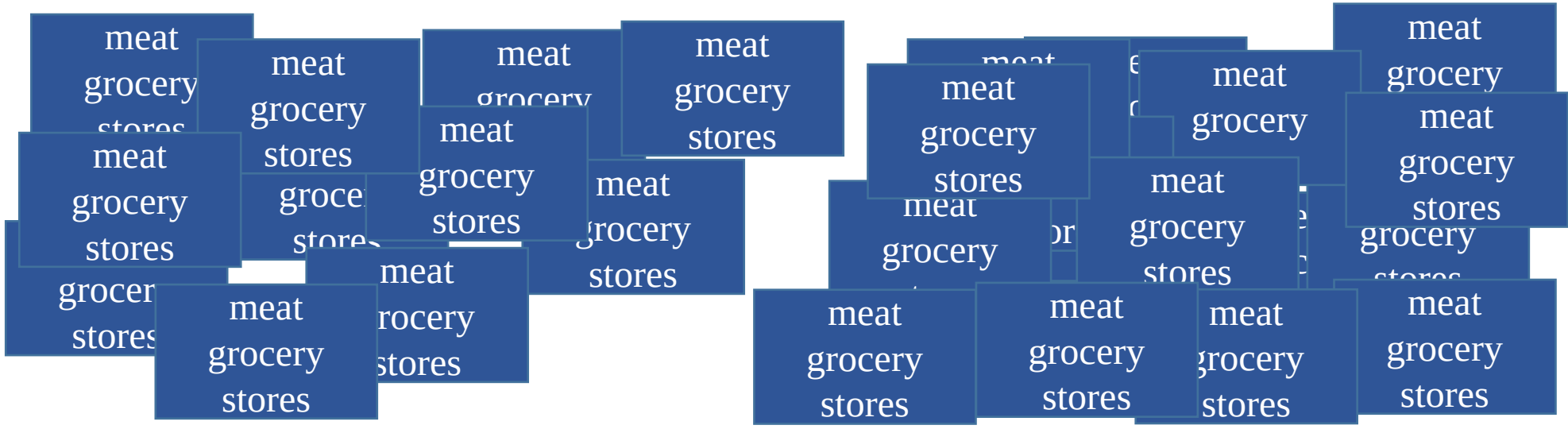
Meanwhile, approximately 10 percent of daily chicken demand in Tehran

(99693. tones) are physical distributed and carry out by (TMMFVO).

Then, according to market demand, they proceed to record every purchase order for the considering market. In the next day the noted demands will be sent to the market.

About **35%** of the meat grocery stores expect demand to be satisfied from **Piroozi Square** and the rest of the stores from **Bahman Square.**

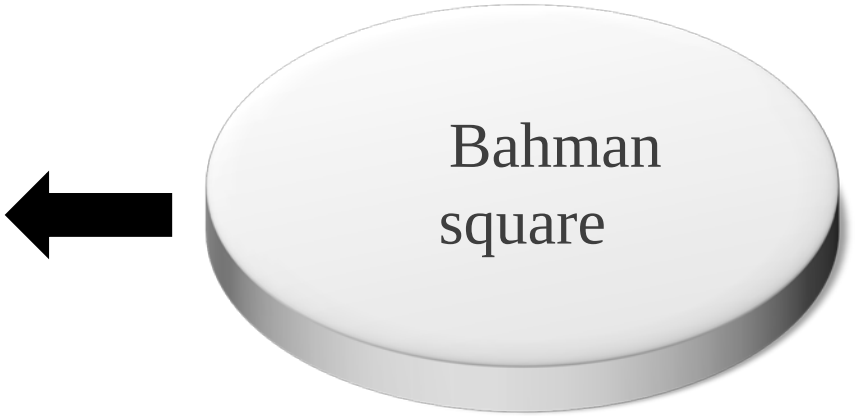
Number of meat grocery stor = 140



At Piroozi square, brokers revise order deliveries from meat groceries according to their market demand estimates for the next day.
Then, according to market demand, poultry meat is deliver from these market squares to meat groceries markets.
In fact, there is a demand registration system.

At Bahman square ,

market demand estimates for the next day. In fact, there is a demand registration system



From these two central markets chicken distribution to 140 local meat grocery markets in Tehran.

From these two central markets, 40 meat grocery markets expected demand from Piroozi central square, and the rest of the meat grocery markets their daily demands satisfy from Bahman central square.

At these two central square brokers, received order from meat grocery market demand for the coming day delivery.

Type of vehicles

Furthermore, there is only two types of vehicles serve in the markets such as:

Nissan Junior (NJ) (with a capacity of 2 tonnes) and

Light Truck (LT) (with a capacity of 3.5 tonnes),

only these two representative types of vehicles are considered in the model.

- This study investigated the transportation structure to provide an optimal model for the daily distribution of poultry meat in Tehran.

Transportation costs of the existing circumstances will be compare to the optimal routing pattern

Base on the optimal routing model how much carbon dioxide less produce?

In 2008, Tehran experienced unfortunate weather conditions for 60 days of the year, roughly quadrupled as that in 2007.
In addition, in 2010 the City's Atmosphere reportedly spent 104 days in unhealthy conditions.
Given the fact that Tehran air pollution, primarily caused diseases of residents of Tehran and increase government expenses for reduce the air pollution.
The World Bank estimated that air pollution in Iran caused approximately 7 billion dollars in damage in 2004, increase to around 8 billion dollars in 2006, jumping to 10 billion dollars in 2010

In this study, we used a Mixed Integer Linear Programming model (MILP the following assumption were made:

- Piroozi and Bahman squares as market centers possess the ability to meet the demand of all meat groceries and no shortage is allow.
- The daily quantity demanded by each meat grocery from Piroozi and Bahman squares is depending of market condition.
- Vehicles have different carrying capacities. In real circumstances, a transportation fleet usually possesses dissimilar vehicles; thereby making use of each of them amounts of time is justified.
- Each vehicle have limited carrying capacity.
- Each vehicle can cover up to N =4 meat grocery markets, as covering too large a number of markets, might lead to microbial spoilage of poultry products.
- The planning horizon is restricted to one period.
- There is infinite access to the transport fleet through renting them out.
- Downtime of vehicles or any unexpected occurrence is not permit.
- shipping cost is proportional to the distance traveled.
- Fixed costs of any type of vehicle have been consider.

$$\min Z = \sum_{v=1}^{f} f_v \sum_{j=1}^{n} X_{njv} + \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{v=1}^{f} C_{ijv}X_{ijv}$$

S.t.

1. $X_{iiv} = 0 \quad \forall i \in R, \forall v \in VS$
2. $\sum_{j=1}^{r} X_{njv} = 1 \quad \forall v \in VS$
3. $\sum_{i=1}^{r} X_{inv} = 1 \quad \forall v \in VS$
4. $\sum_{v=1}^{f}\sum_{i=1}^{r} X_{ijv} = 1 \quad \forall j \in R \quad i \neq j$
5. $\sum_{v=1}^{f}\sum_{j=1}^{r} X_{ijv} = 1 \quad \forall i \in R \quad i \neq j$
6. $\sum_{i=1}^{r} X_{ijv} - \sum_{j=1}^{r} X_{jiv} = 0 \quad \forall j \in R, \forall v \in VS$
7. $\sum_{i=1}^{r} d_i \left(\sum_{j=1}^{n} X_{ijv} \right) \leq Cap_v \quad \forall v \in VS$
8. $\sum_{i=1}^{n}\sum_{j=1}^{n} t_{ij}X_{ijv} \leq T \quad \forall v \in VS$
9. $X_{ijv} \in \{0,1\}$

objective function and nine independent constraints

Where R represents a set of local grocery markets (R = {1, 2, …, r})

MD = denotes central distribution squares (e.g. Bahman and Piroozi Squares),

N = stands for overall sets of problem (Local markets, plus Central squares, from mathematical perspective: N = (R ∪ MD) = {1, 2, …, n}).

VS= implies a set of the shipping fleet with f members of types of vehicles (VS = {1, 2, …, f})

t_{ij} =signifies the traveling time from knot i to knot j (with time for each direction considered a unit value, in other words, the transport fleet is able to serve a limited number of markets).

T = represents the number of routes in which a vehicle is allow to travel.

d_i = the demand quantity of local markets, Cap_v suggests the portable capacity of the v-th vehicle, C_{ijv} is the cost of transportation of products from the point i to the point j using v-th vehicle and f_v is the fixed costs of each transporting vehicle, Lastly, X_{ijv} marks the decision variable of the model, expressed as an integer.

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X_{ijv} = marks the decision variable of the model, expressed as an integer.

$$X_{ijv} \begin{cases} 1 & \text{If the } v_{th} \text{ vehicle is responsible for provide services to knot i then to knot j} \\ 0 & \text{Otherwise} \end{cases}$$

In situations where the number of vehicles is considered infinite, **FSMVRP model** (Fleet Size and Mix Vehicle Routing Problem), , proposed by Golden et al. (1984), usually be applied.

Otherwise, for a given number of vehicles in a fleet, the **HFVRP model** (Heterogeneous Fixed Fleet Vehicle Routing Problem) described by Taillard (1999), is preferable.

Both models aim to minimize fixed and variable costs. particularly, various studies such Li, Golden & Wasil (Li et al. 2007) in which the minimization of fixed and variable costs separately, or both fixed and variable costs are taken together into consideration.

In the present study, we applied a Fleet Size and Mix Vehicle Routing Problem (FSMVRP) with an unlimited number of each type of vehicle. (Forghani and Jafari 2013).

Moreover, in this work, in order to consider the time constraints as well as maintaining the quality of poultry meat, each time stop of the vehicle in any market has been taken in to account as a time unit.

Hence, every vehicle can serve only up to a maximum number of N =4 markets. In addition, the conditions of multi-depot and multi-trip were model as well.

Constraint

Constraint 1: indicates that none of the vehicles are not allowed to return immediately to a knot in which it has begun. To put it another way, there should be no arrows (route) in the graph of the problem with identical start and end.

Constraint 2: suggests that the starting point of travel of each vehicle must be one of central squares market. Because the vehicle primarily loads from the central square and then move into the local markets.

Constraint 3: represents that the culmination of the trip for each vehicle is a storage facility. Vehicles should be marked after a course and cargo completion; in order to subsequent, it should refer to the central warehouse.

Constraints 4 and 5 show that in any planning period, a single vehicle can only once provide service to each of the local markets. The mentioned vehicles should come from a former place, and then move to a latter place.

Constraint 6: ensures that if a vehicle moved to a market and presented a service, only the same vehicle must be leave the respective market.

Constraint 7: implies the maximum capacity of any vehicle. In other words, given the demand of different local markets, the amount of poultry transported by any vehicle should not exceed from its capacity.

Constraint 8: suggests that a vehicle can serve a maximum r markets. The number of routes which vehicle can travel should not exceed T.

Constraint 9 is also required to guarantee that each variable of X_{ijv} can only take a value of zero or one.

Results and Discussion

Table 1. Comparing optimal Results of Three Days with Existing Transport Conditions of those Days

		Joint	Piroozi square		Bahman		Compering optimal and existing conditions		
		optimal	optim	curr	optima	curr	Joint squares	Piroozi square	Bahman
Day I	Number of markets	97	50	50	47	47	-	-	-
	Total demand (tonnes)	79.44	23.09	23.09	56.35	56.35	-	-	-
	Total distance traveled (km)	762.9	417.5	469	461.3	1102.	809(51.47)	51.5(10.98)	641.6(58.17)
	Total cost (thousands of Rials)	39784	16838	1776	26776	3872	16698(29.56)	922(5.19)	11946(30.85)
	The number of vehicles required	27	14	15	16	34	22(44.9)	1(6.67)	18(52.94)
	Cost per market (thousands of	410.14	336.76	355.2	569.7	823.8	172.14(29.56)	18.44(5.19)	254.17(30.85)
	Cost per tonne (thousands of	500.82	729.33	769.2	475.17	687.1	210.20(29.56)	39.94(5.19)	212(30.85)
	Cost per course (thousands of	1473.48	1202.7	1184	1673.5	1138.	-320.79(27.83)	-18.71(-1.58)	-534.62(-46.94)
Day II	Number of markets	100	43	43	57	57	-	-	-
	Total demand (tonnes)	67.08	13.03	13.03	54.05	54.05	-	-	-
	Total distance traveled (km)	789.3	405.6	426.2	588.4	1015.	652(45.24)	20.6(4.83)	426.7(42.04)
	Total cost (thousands of Rials)	37693	12976	1375	30992	3853	14596(27.91)	783(5.69)	7538(19.56)
	The number of vehicles required	27	11	13	19	32	18(40)	2(15.38)	13(40.63)
	Cost per market (thousands of	376.93	301.77	319.9	543.72	675.9	145.96(27.91)	18.21(5.69)	132.25(19.56)
	Cost per tonne (thousands of	561.9	995.76	1055.	573.4	712.8	217.59(27.91)	60.09(5.69)	139.46(19.56)
	Cost per course (thousands of	1396.04	1179.6	1058.	1631.2	1204.	-234.06(-20.14)	-121.252(-	-427.10(-35.47)
Day III	Number of markets	86	44	44	42	42	-	-	-
	Total demand (tonnes)	49.92	14.13	14.13	35.79	35.79	-	-	-
	Total distance traveled (km)	667.6	412.6	440	413.4	793.5	565.9(45.88)	27.4(6.23)	380.1(47.9)
	Total cost (thousands of Rials)	29216	13640	1475	21459	2858	14116(32.58)	1112(7.54)	7121(24.92)
	The number of vehicles required	24	11	11	13	27	14(36.84)	0(0)	14(51.85)
	Cost per market (thousands of	339.72	310	335.2	510.93	680.4	164.14(32.58)	25.27(7.54)	169.55(24.92)
	Cost per tonne (thousands of	585.29	965.16	1043.	599.66	798.6	282.79(32.58)	78.68(7.54)	198.99(24.92)
	Cost per course (thousands of	1217.33	1240	1341.	1650.7	1058.	-77.02(-6.75)	101.09(7.54)	-592.17(-55.94)

The percentage difference between the different modes has been shown in parentheses.

How society benefit from optimal distribution?

The result from optimal models indicate that, for three days the distance traveled was reduce to 809 km, 652 km and 566 km respectively by all Nissan Junior and Light Truck (LT) .

The distance reduction for three day are 51.5%, 45.2% and 45.9%, respectively.

- According to the Iran Transportation and Shipping Organization in 2016, truck of less than 3.5 tons capacity a fuel consumption are between 16 and 20 liters per 100 kilometers

- Therefore, the average consumption of fuel was set at these truck with less than 3.5 tons capacity , 17.8 liters per 100 kilometers.
- (0.178 liters / km).

How calculate the reduced fuel consumption?

RFC= RD*FC

RFC: is Reduced Fuel Consumption,

RD: Reduced Distance form optimal model

FC: is Fuel Consumption per Km

for three days, the fuel consumption is reduced by 144, 116 and 100 liters per day respectively, with an average daily fuel reduction was 120.3 liters fuel per day.

Considering the average world price of diesel fuel in the world in 2016 is $ 1.09 per liter (equivalent to 45747 Rials).

Therefore, the cost of fuel consumption is reduce by $156.9, $126.5 and $109.8 dollars in the three days respectively,

with an average of $ 131.09 in fuel consumption per day.

How society benefit from optimal distribution?

- The average Price of one kilogram poultry meat in Tehran was $1.90
- The result from optimal models indicate that, on average the price of poultry meat will reduce by 0.25 cents per kilogram
- Base on the optimal model the price of poultry meat will reduce by about 14% percent in local meat grocery market.

How calculate the carbon dioxide?

Ameri and Zahid (2013), in their study, they indicate that in Iran one liter of gasoline, produce an average of 480 grams of carbon dioxide per kilogram.

$$RC=AP*TFCR \qquad (2)$$

RC = is CO2 reduction,

AP = has an average produced CO2 per liter and

TFCR = is total fuel reduction.

Base on optimal model by reducing the fuel consumption of vehicles in the three days of the study are, 69.12, 55.71 and 48.35 kg of CO2 are less produce in Tehran respectively.

The average per day 57.72 kg less CO2 is produced that mean less air pollution in Tehran .

- Drivers' benefits from increased transportation efficiency increased by 27.8%, 20.1% and 6.75% respectively in three days, respectively
- On average, drivers' daily benefits increase by 18.23% percent.

- Accordingly, in three days, the benefits of lower fuel consumption are $3.59, $2.81, and $2.51 dollar respectively, with an average of about $ 3 per day on social benefits.

Policy implication

- The optimizations revealed by the model decrease daily expenses compared to the existing conditions, therefore we can improve efficiency in transportation systems for all kind of meat.
- These reductions in transportation costs translate into additional revenue for truck owners.
- Earnings more income by truck owner can be used to improve the existing transport system. Such as, GPS could be installed to track, or cooling systems in the vehicles could be upgraded and improved in better maintain the quality of the chicken meat.

- Reduced indirect costs; including fuel consumption, reduce environmental pollution and reduction of traffic.
- These reductions are achieved through less vehicle use and less distance travelled by trucks on different days as generated by the optimal model.

- The demand for poultry meat is seasonal demand:
- Data collected on supply and demand on poultry for various days can aid in generating more accurate forecasting both for week, months, and for longer-term planning.
- By having more data we can even forecasting the seasonal demand and supply of poultry meat, and base on the result of forecasting we can develop the seasonal forecasting optimal route models.

- Since the issue of route traffic is an important factor that can significantly increase fuel consumption and affect distribution times, future research should analyze the impact of traffic.
- In addition, it is vital to consider the time window based on the total time over a course and stopping times.

- In future study by using MILP with benefit – cost analysis model consider, if Tehran Municipality Management of fruit and vegetables Organization (TMMFVO), by investing to build a one central meat market instated of having two central markets for answering these questions:
- How much investment cost?
- How much cost saving in transportation?
- How much the price of poultry meat reduce?
- How much the air pollution will decreased?

Thank you