EPIDEMIC MODELLING

[ANSWER - 2a]

Human perspective is taken into consideration to model this epidemic. The reason being that movement of humans can be controlled to a great extent unlike the pathogens that can exist as aerosol in air and even on surfaces like metal, plastic, glass etc and therefore, it is not feasible to track it's existence and movement.

A city has following zones.

1. **Extreme Congestion Zone (ECZ)**
2. **High Congestion Zone (HCZ)**
3. **Moderate Congestion Zone (MOCZ)**
4. **Mild Congestion Zone (MICZ)**
5. **Moderately Spaced Zone (MSZ)**
6. **Safe Space Zone (SSZ)**
7. **Ideal Space Zone (ISZ)**
8. **Sparse Zone (SPZ)**
9. **Dispersed Zone (DZ)**

Details of zones are given below

Zone	Average Inter-person space (radial) in Dwelling Units (DU)	Population living (in %)
ECZ	<=0.5 meters	15 %
HCZ	More than 0.5 but < 1 meter	30 %
MOCZ	1 to 1.5 meters	35 %
MICZ	1.5 to 2 meters	10 %
MSZ	2 to 2.5 meters	7 %
SSZ	2.5 to 3 meters	2 %
ISZ	3 to 5 meters	0.8 %
SPZ	5 to 8 meters	0.1 %
DZ	>8 meters	0.1 %

We know that the transmission of infection is possible with probability 0.7 if the carrier is within 2 meter radius of another person for 5 seconds or more.

ASSUMPTION 1
Assuming the number of persons coming in contact with infected persons under above mentioned conditions per DAY zone wise is given below.

Zone	No of persons within 2m of Carrier for 5s or more per day
ECZ	10
HCZ	10
MOCZ	9
MICZ	8
MSZ	7
SSZ	5
ISZ	3
SPZ	2
DZ	2

This will help to calculate the spread of the virus.

THE MODEL

Given :
n : Total Population of the City
r : Population Per Carrier
x : Percentage of Population Infected

zp : list of percentage of people living in each zone
cp : list of number of people coming in contact with each carrier per Day (assumption-1)

To Find :
Time : Time (in days) required for x% population to be infected

The Approach :

Step 1 - Calculate number of people infected using x and n. (Say, Pop)

$$\text{Pop} = x\% \text{ of } n$$
$$= (x*n)/100$$

Step 2 - Calculate initial number of carriers per zone using zp, n, r (Say, ZW_In)

$$ZW\_In = (zp * n) / (100 * r)$$

This will result in list.

Step 3 -[ANSWER - 2b(i)] Calculating number of days (t) required for x% of n population to be infected.

This will summation equated with Pop

$$0.7 * \sum ZW\_In_n \, (cp_n)\text{^}t >= \text{Pop}$$

n = 1-9 (indication each zone)

Starting from t = 1, this equation will be evaluated and compared with Pop. If sum is less than Pop, the equation will be equated again for t=2 and so on until the sum becomes greater than or equal to Pop.

The value of t when sum becomes greater than or equal to Pop will be the number of days required for x% to be infected by the virus under normal circumstances i. e. no population is restricted to stay indoors.

0.7 is the probability of a person getting infected by a carrier when the carrier is in 2m radius of the person and stays there for 5s or more.

Mobility of Population (MOP) at three levels:

Static (S) – everyone stays at home
Dynamic (D) – normal movement for work etc.
Sensitive (SN) – only sick (possibly infected) stay at home/quarantine

Assuming % of population coming out of their homes under these 3 MOP levels

ASSUMPTION - 2

MOP Level	% of People out of Dwelling Area	Percentage of No of persons within 2m of Carrier for 5s or more per day will be reduced by
Static	30% (only Health care workers,..etc)	0.5
Dynamic	50 % (Essential services workers..etc)	0.3
Sensitive	90 %	0

For calculating Time in each of these levels, the process will be the same. The only difference will be in calculating the number of carriers.
Population considered will be x% of total population, x is based on % of People out of Dwelling Area.

A prolog program has been made to support the model. Snippets from which are given below.

estimate

Total Population (n) is

2000000

Number of Persons per Carrier (r) is

10000

% of Population Infected (x) is

50

1000000 people will be infected in
5 Days

Number of days taken during each MOP level

STATIC : 1000000 people will be infected in 6 Days

DYNAMIC : 1000000 people will be infected in 6 Days

SENSITIVE : 1000000 people will be infected in 5 Days

true

estimate

Total Population (n) is

2000000

Number of Persons per Carrier (r) is

1000

% of Population Infected (x) is

80

1600000 people will be infected in
4 Days

Number of days taken during each MOP level

STATIC : 1600000 people will be infected in 5 Days

DYNAMIC : 1600000 people will be infected in 4 Days

SENSITIVE : 1600000 people will be infected in 4 Days

true

[ANSWER -2b(ii)]

We can see that Static mobility of the population is the best mode to delay the spread of the virus as Dynamic and Sensitive do not make any noticeable difference.

[ANSWER -2b(iii)]

The initial days of the epidemic are very crucial. If the population's mobility is limited to Static, the spread of the virus will be easy to contain. Else it starts increasing exponentially and becomes very difficult to contain.

PROGRAM

```
% To Calculate Number of Carriers Zonewise
zonewise_infected([],_,_,_,[]).
zonewise_infected([H|T],TP,R,A,[M|N]):-
   F is (A*H*TP)/(R*100),
   M is floor(F),
   zonewise_infected(T,TP,R,A,N).

% To Calculate Number of People infected in each zone w.r.t. Days
infected_pop_zw([],[],_,[]).
infected_pop_zw([H|T],[M|N],Days,[P|Q]):-
   P is H*(M^Days),
   infected_pop_zw(T,N,Days,Q).

% To Calculate Total infected Population
total_infected_pop([],0).
total_infected_pop([H|T],Sum):-
   total_infected_pop(T,Sum1),
   Sum is 0.7*(H+Sum1).

% Finding Number of Days
count_days(ZWIn,CPop,I,Pop,Time):-
   V is I+1,
   infected_pop_zw(ZWIn,CPop,V,InfectedInNDays),
   total_infected_pop(InfectedInNDays,S),
    (   S<Pop->  count_days(ZWIn,CPop,V,Pop,Time);
     S>=Pop ->  Time is V) .

estimate():-
   write('Total Population (n) is '),
   read(N),

   write('Number of Persons per Carrier (r) is '),
   read(R),
```

```
% Percentage of Population living in each zone
append([15,30,35,10,7,2,0.8,0.1,0.1],[],ZonePopPercent),

%Assumed Number of People coming in contact with Carriers
% under given conditions per DAY
append([10,10,9,8,7,5,3,2,2],[],ContactedPop),

write('% of Population Infected (x) is '),
read(X),

% Number of infected people
Pop is (N*X)/100,
write(Pop),write(' people will be infected in '),

% Calculating Number of Carriers present in each intially
nl,
zonewise_infected(ZonePopPercent,N,R,1,ZoneWiseInfected),

% Counting Number of Days in which given % of Population
% will be affected
count_days(ZoneWiseInfected,ContactedPop,0,Pop,T),
write(T), write(' Days'),nl,

write('Number of days taken during each MOP level'),nl,
%   Calculations for Static MOP
write('STATIC : '), write(Pop),write(' people will be infected in '),
St is 0.2*N,
zonewise_infected(ZonePopPercent,St,R,0.5,ZoneWInfected),
count_days(ZoneWInfected,ContactedPop,0,Pop,T1),
write(T1), write(' Days'),nl,

%  Calculations for Dynamic MOP
write('DYNAMIC : '), write(Pop),write(' people will be infected in '),
Dy is 0.4*N,
zonewise_infected(ZonePopPercent,Dy,R,0.7,ZoneWInfected1),
count_days(ZoneWInfected1,ContactedPop,0,Pop,T2),
write(T2), write(' Days'),nl,

%  Calculations for Senstive MOP
write('SENSITIVE : '), write(Pop),write(' people will be infected in '),
Se is 0.8*N,
zonewise_infected(ZonePopPercent,Se,R,1,ZoneWInfected2),
count_days(ZoneWInfected2,ContactedPop,0,Pop,T3),
```

```
write(T3), write(' Days'),nl

.
```