Section A

Model 1

Sets

ID	Set of Import Depots (ID)
LVC	Set of Local Vaccination Centres (LVC)
CCD	Set of Census Collection Districts (CCD)
D	Set of Vaccine Delivery Arcs from ID to LVC
R	Set of routes a citizen can travel along between CCDs and LVCs

Data

$ImportC_i$	Cost to import vaccines to $i \in ID$
P_c	Population of $c \in C$
$DelC$	Cost to deliver vaccines from an ID to an LVC per kilometre per dose
$DelL_d$	Length in kilometres of $d \in D$
$o_d \in ID$	Origin ID of vaccine travelling along $d \in D$
$v_d \in LVC$	Destination of vaccine travelling along $d \in D$
$DriveL_r$	Length in kilometres of $r \in R$
$DriveC$	Cost per kilometre for a citizen to travel
$t_r \in LCD$	LVC that a citizen is travelling too along $r \in R$
$f_r \in CCD$	CCD that a citizen is travelling from along $r \in R$
Cap	Capacity of Vaccines which can be stored at an ID
$AMax$	Maximum number of vaccine doses which can be administered at an LVC
$UpgradeC_l$	Cost to upgrade the maximum dosage administered at $l \in LVC$
$Increase$	How much the capacity of $l \in LVC$ increases if upgraded
$CloseC_l$	Cost savings when $l \in LVC$ is closed.
M	The maximum population of all CCD's

Variables

x_d	Number of vaccine doses being delivered along $d \in D$
y_i	Number of vaccine doses being imported to $i \in ID$
z_r	Number of citizens travelling to get their vaccine along $r \in R$
s_l	Number of vaccine doses stored at $l \in LVC$
u_l	$\begin{cases} 1, \text{if the capacity } of\ l \in LVC \text{ will be upgraded} \\ 0, \text{otherwise} \end{cases}$
c_l	$\begin{cases} 1, \text{if } l \in LVC \text{ has been closed} \\ 0, \text{otherwise} \end{cases}$

a_r $\begin{cases} 1, \text{if citizens are allowed to travel along } r \in R \text{ to get their vaccines} \\ 0, \text{otherwise} \end{cases}$

Objective

$$\min \sum_{i \in I} ImportC_i \times y_i + \sum_{d \in D} DelC \times DelL_d \times x_d + \sum_{r \in R} DriveC \times DriveL_r \times z_r + \sum_{l \in LVC} UpgradeC_l \times u_l - \sum_{l \in LVC} CloseC \times c_l$$

Constraints

Ensuring the number of vaccine doses imported to each ID does not exceed capacity:

$$y_i \leq Cap \qquad \forall\, i \in ID$$

Ensuring the number of vaccine doses leaving an ID does not exceed the number of vaccines there:

$$\sum_{\substack{d \in D \\ s.t\ o_d = i}} x_d \leq y_i \qquad \forall\, i \in ID$$

Ensuring the number of vaccines stored at an LVC is equal to the number of incoming vaccines from IDs minus the number of vaccines administered that week:

$$s_l = \sum_{\substack{d \in D \\ s.t\ v_d = l}} x_d - \sum_{\substack{r \in R \\ s.t\ t_r = l}} z_r \qquad \forall\, l \in LVC$$

Ensuring that a LVC cannot be upgraded and closed at the same time:

$$u_l + c_l \leq 1 \qquad \forall\, l \in LVC$$

Ensuring the number of vaccines administered at an LCD does not exceed capacity. Note that if the LVC is closed the capacity should be 0, if the LVC is normal the capacity should be AMAX and if the LVC is upgraded the capacity should be Amax + Increase:

$$\sum_{\substack{r \in R \\ s.t\ t_r = l}} z_r \leq AMax(1 - c_l) + Increase \times u_l \qquad \forall\, l \in LVC$$

Ensuring that the entire population of a CCD is vaccinated:

$$\sum_{\substack{r \in R \\ s.t\ f_r = c}} z_r = P_c \qquad \forall\, c \in CCD$$

Ensuring that citizens can only travel to one LVC to get their vaccination. That is, there is only one $r \in R$ that can be travelled along from a given CCD:

$$\sum_{\substack{r \in R \\ s.t\ f_r = c}} a_r = 1 \qquad \forall\, c \in CCD$$

Ensuring that if a route is closed, no citizens can travel along it:

$$z_r \leq M \times a_r \qquad \forall\, r \in R$$

Non-Negativity Constraints:

$$x_d \geq 0 \qquad \forall\, d \in D$$

$$y_i \geq 0 \qquad \forall\, i \in ID$$

$$z_r \geq 0 \qquad \forall\, r \in R$$

$$s_l \geq 0 \qquad \forall\, l \in LVC$$

Model 2

Sets

CCD Set of Census Collection Districts (CCD)

H Set of all Public Health Options to try and eradicate the virus

Data

$Budget$ Budget that can be used on public the health options to try and eradicate the virus

$ECost_{c,h}$ Cost of using option $h \in H$ in $c \in CCD$

$EProb_h$ Probability of option $h \in H$ eradicating a virus in a given CCD

Variables

$x_{c,h}$ $\begin{cases} 1, \text{if option } h \in H \text{ should be used in } c \in CCD \\ 0, \text{otherwise} \end{cases}$

$LogP$ The logarithm of the probability of eradication in Pacific Paradise

Objective

$$\max LogP$$

Constraints

Ensuring that only 1 health option will be used in each CCD

$$\sum_{h \in H} x_{c,h} = 1 \qquad \forall\, c \in CCD$$

The total probability of eradication in pacific paradise must be equal to the product of each individual probability of eradication. This is equivalent to saying that the logarithm of the total eradication probability is equal to the sum the individual probability logarithms. Hence:

$$\sum_{c \in CCD} \sum_{h \in H} \log(EProb_h) \times x_{c,h} = LogP$$

Ensuring that the total cost of implementing the health options in each CCD is less than the budget:

$$\sum_{c \in CCD} \sum_{h \in H} ECost_{c,h} \times x_{c,h} \leq Budget$$

The logarithm of a number between 0 and 1 (probabilities must be between these values) results in a negative number. Hence:

$$LogP \leq 0$$

Section B

Communication 6

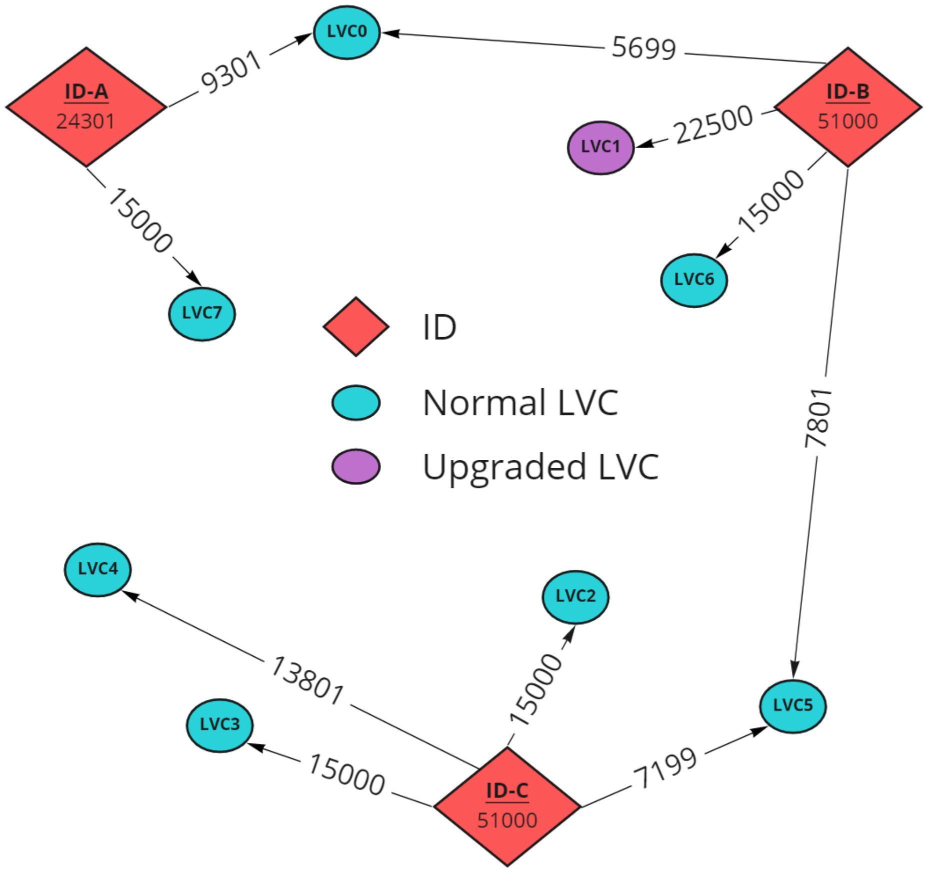
The optimal cost of the vaccine distribution when considering possible upgrades would be:

$23250359

You will need to import vaccines to ID's as shown below:

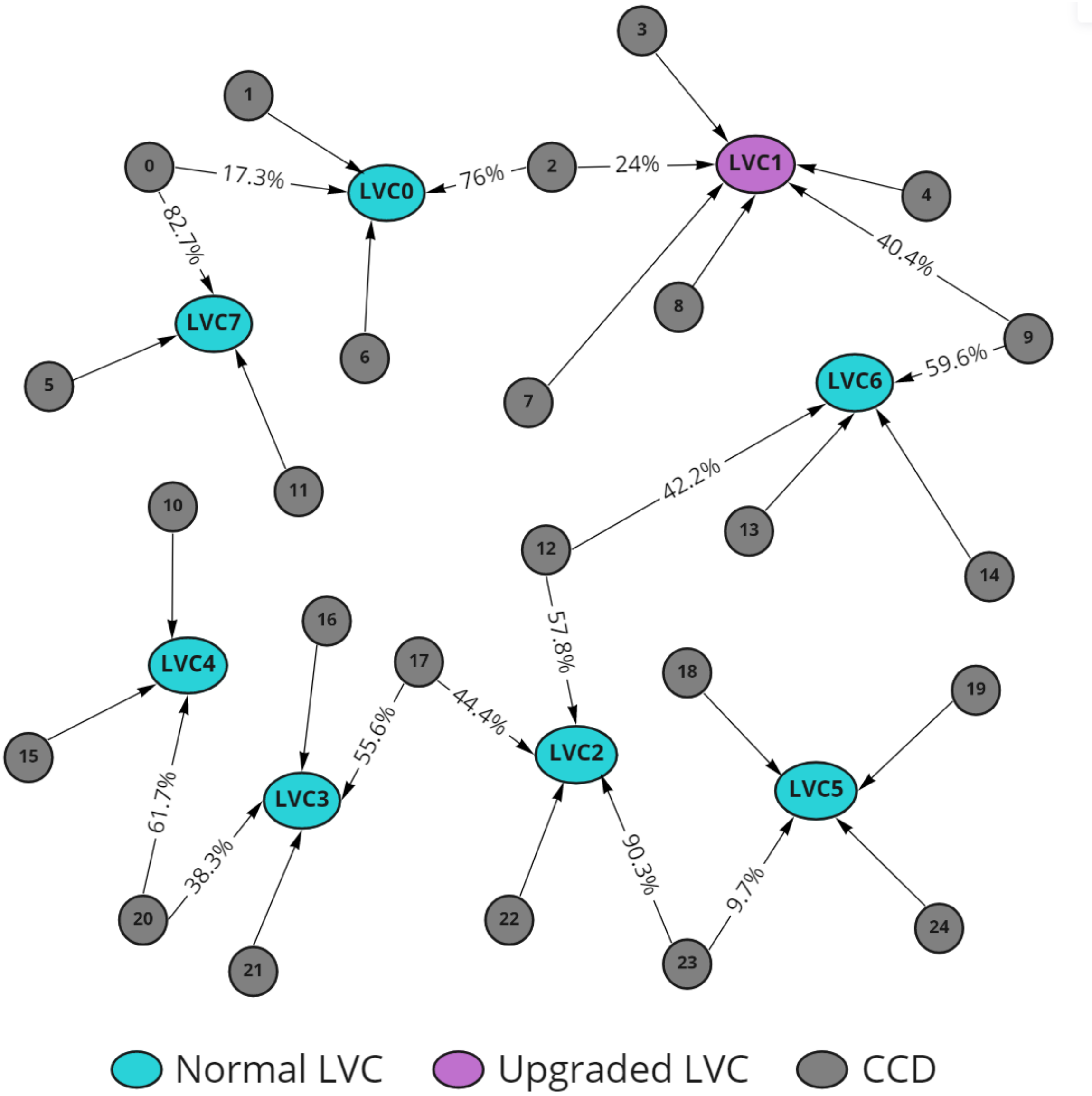
Import Depot	Vaccine Doses Imported
ID-A	24301
ID-B	51000
ID-C	51000

Vaccines should be distributed from ID's to LVC's as shown below. This diagram also outlines that **LVC1 should be upgraded**, while all other LVC's should remain untouched:



LVC	LVC0	LVC1	LVC2	LVC3	LVC4	LVC5	LVC6	LVC7
Vaccines Administered	15000	22500	15000	15000	13801	15000	15000	15000

The below graph shows how citizens should travel from their given CCD to an LVC to get their vaccination. In the case where citizens from a CCD can travel to multiple LVC's a percentage is given to show what proportion of the CCD should go to each LVC:



Communication 7

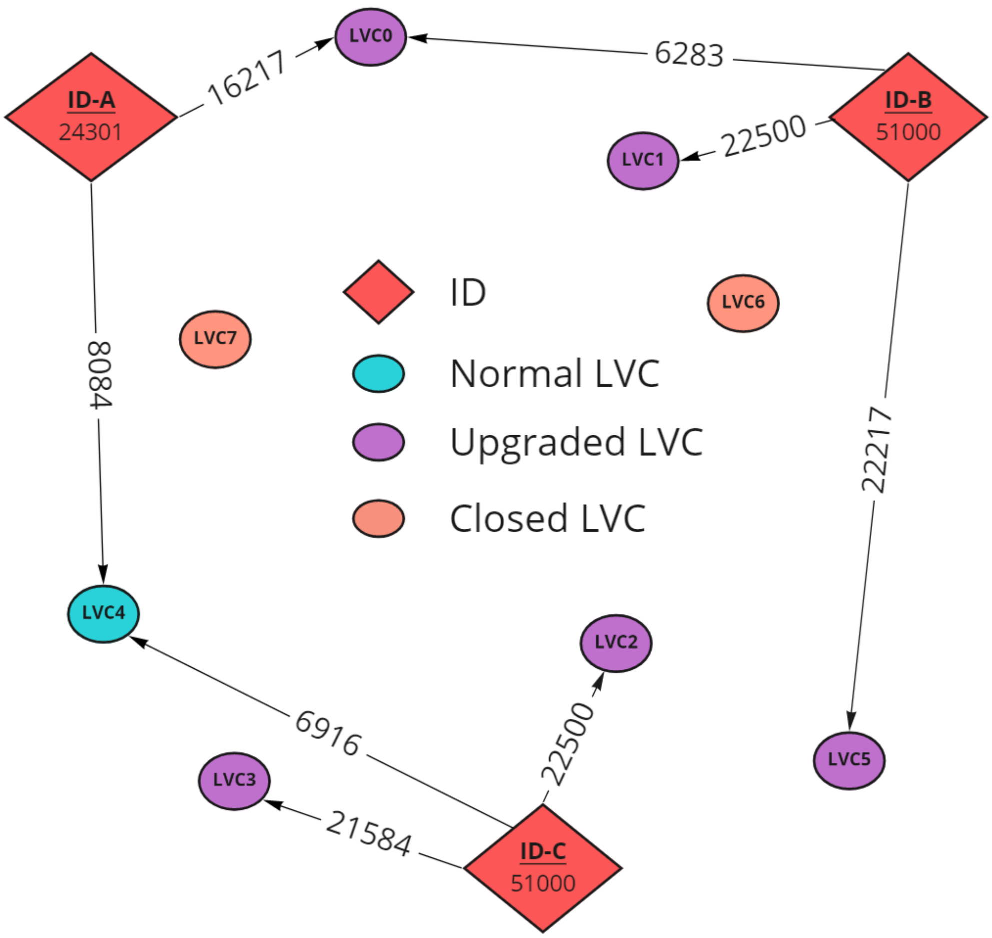
The optimal cost of the vaccine distribution when considering possible upgrades and closures would be:

$19191430

You will need to import vaccines to ID's as shown below:

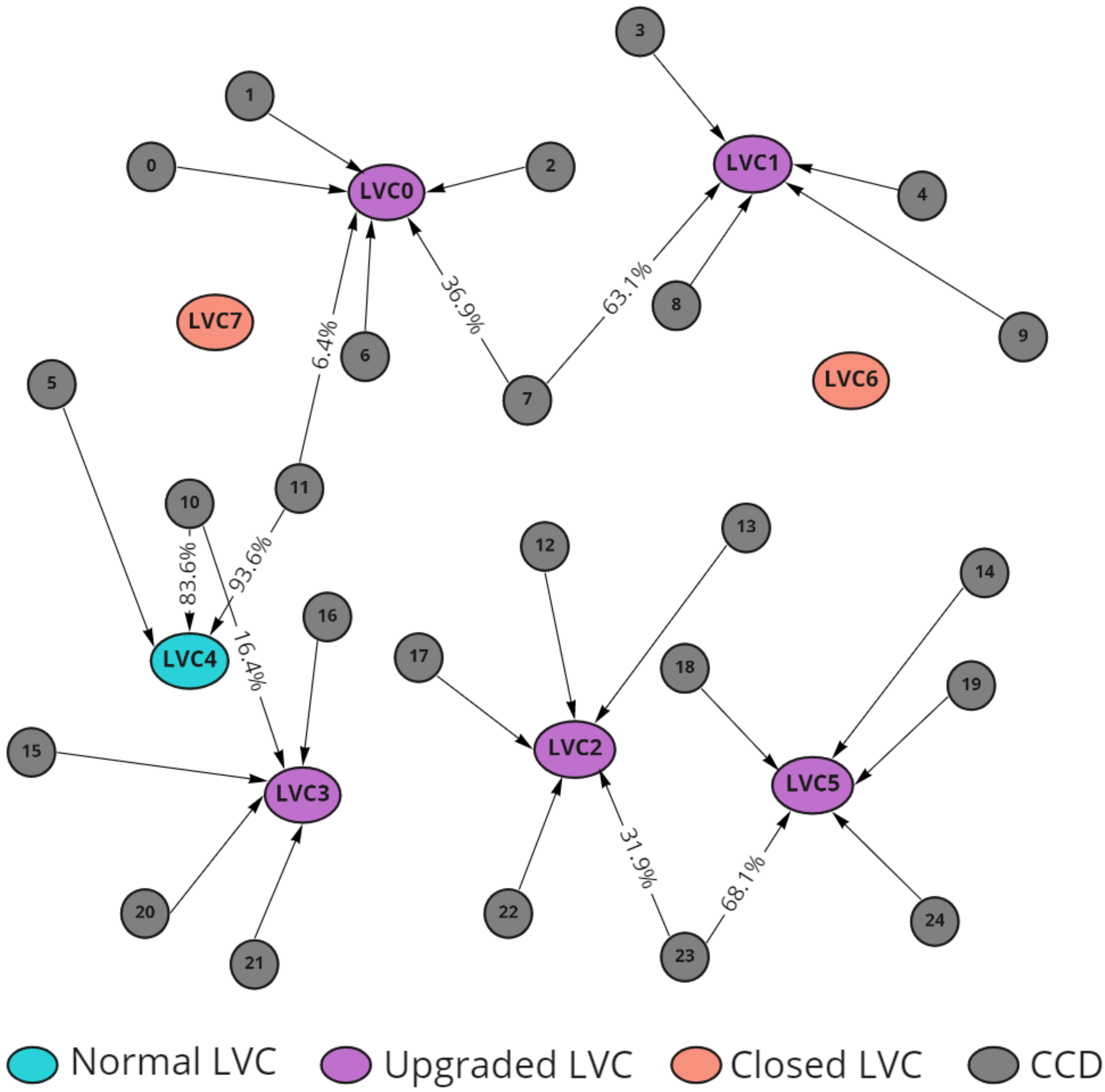
Import Depot	Vaccine Doses
ID-A	24301
ID-B	51000
ID-C	51000

Vaccines should be distributed from ID's to LVC's as shown below. This diagram also outlines that **LVC0, LVC1, LVC2, LVC3 and LVC5 should be upgraded**. Similarly, **LVC6 and LVC7 should be closed** while all other LVC's should remain untouched:



LVC	LVC0	LVC1	LVC2	LVC3	LVC4	LVC5	LVC6	LVC7
Vaccines Administered	22500	22500	22500	21584	15000	22217	0	0

The below graph shows how citizens should travel from their given CCD to an LVC to get their vaccination. In the case where citizens from a CCD can travel to multiple LVC's a percentage is given to show what proportion of the CCD should go to each LVC:



Communication 8

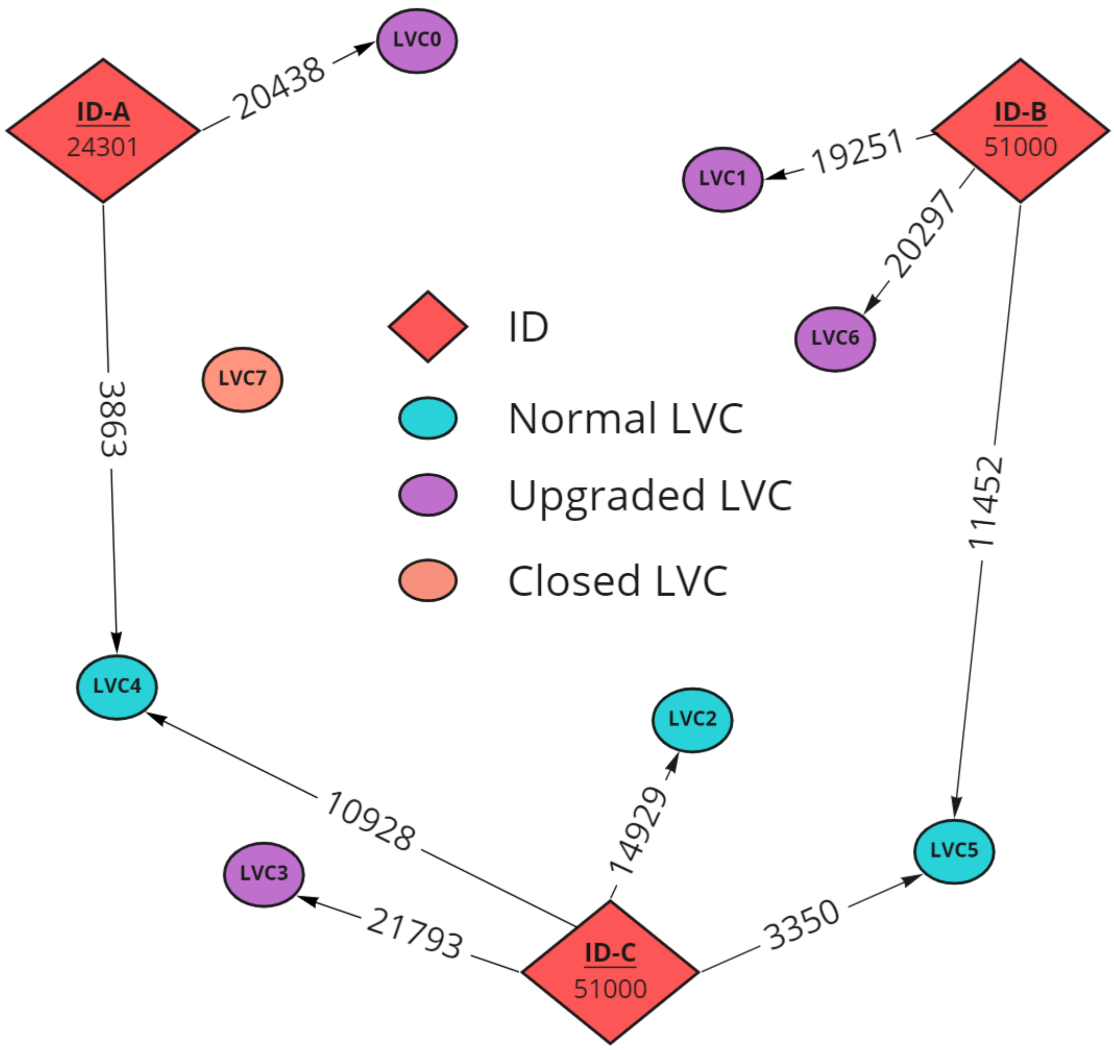
The optimal cost of the vaccine distribution when considering possible upgrades, closures and assigning each CCD to one LVC would be:

$22574416

You will need to import vaccines to ID's as shown below:

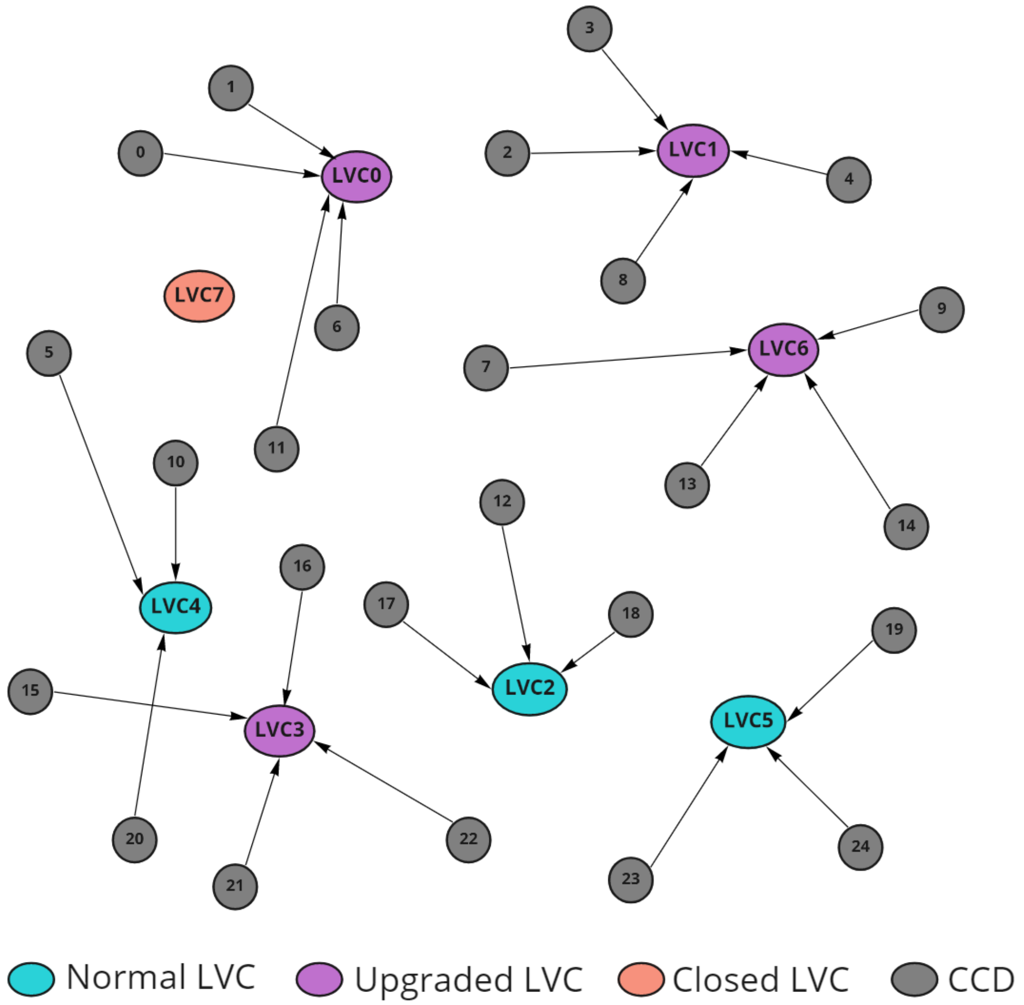
Import Depot	Vaccine Doses
ID-A	24301
ID-B	51000
ID-C	51000

Vaccines should be distributed from ID's to LVC's as shown below. This diagram also outlines that **LVC0, LVC1, LVC3 and LVC6** should be upgraded. Similarly, **LVC7** should be closed while all other LVC's should remain untouched:



LVC	LVC0	LVC1	LVC2	LVC3	LVC4	LVC5	LVC6	LVC7
Vaccines Administered	20438	19251	14929	21793	14791	14802	20297	0

The below graph shows how citizens should travel from their given CCD to an LVC to get their vaccination:



Communication 9

The optimal cost to ensure the overall probability of eradicating the virus in all CCD's is at least 80% is: **$ 6726000**

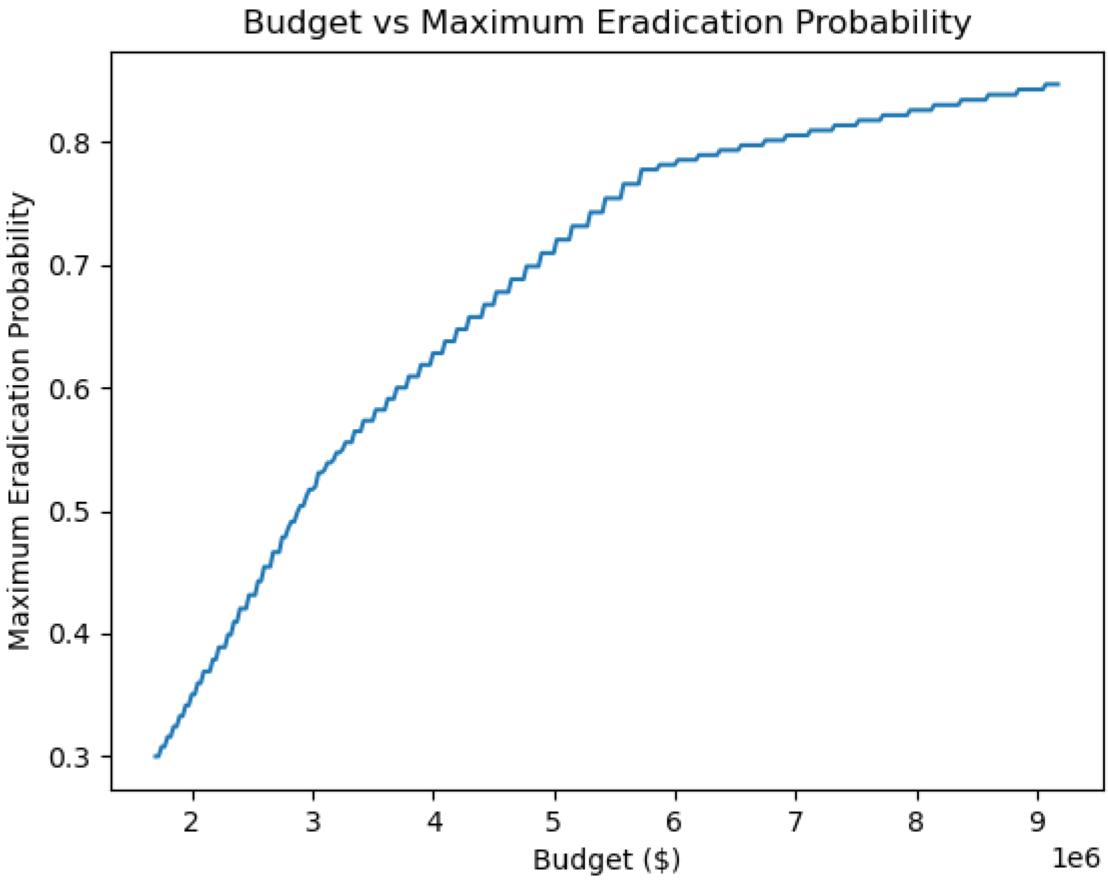
The health options that should be used in each CCD as well as the overall probability is shown below:

CCD	Option	Cost ($)	CCD	Option	Cost	CCD	Option	Cost ($)
0	D	400000	9	C	245000	17	D	418000
1	C	248000	10	D	416000	18	C	221000
2	C	205000	11	C	245000	19	C	250000
3	C	205000	12	C	202000	20	C	222000
4	C	237000	13	C	231000	21	C	200000
5	C	219000	14	C	201000	22	C	203000
6	D	435000	15	D	404000	23	C	218000
7	C	239000	16	C	222000	24	D	428000
8	C	212000	**Total Probability:**		80.2%	**Total Cost ($):**		6726000

A = 95%, B=97.5%, C=99%, D=99.5%

Communication 10

A graph that demonstrates the maximum eradiation probability for a given budget is shown below:



Some example budgets were selected and the strategy to maximise the eradication probability was shown alongside them:

Budget ($)	CCD's Using a Given Health Option				Eradication Probability (%)	Actual Cost ($)
	95.0%	97.5%	99.0%	99.5%		
2,000,000	0, 2, 3, 4, 5, 7, 11, 12, 13, 14, 15, 16, 19, 20, 23, 24	1, 6, 8, 9, 10, 17, 18, 21, 22	-	-	35.0	1988000
2,500,000	0, 2, 3, 4, 5, 11, 14, 24	1, 6, 7, 8, 9, 10, 12, 13, 15, 16, 17, 18, 19, 20, 21, 22, 23	-	-	43.1	2468000
3,000,000	4	0, 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	-	-	51.7	2957000
3,500,000	-	0, 1, 4, 5, 6, 7, 8, 9, 10, 11, 13, 15, 16, 17, 18, 19, 20, 21, 23, 24	2, 3, 12, 14, 22	-	57.3	3421000
4,000,000	-	0, 1, 6, 7, 8, 9, 10, 11, 13, 15, 17, 18, 19, 24	2, 3, 4, 5, 12, 14, 16, 20, 21, 22, 23	-	62.8	3986000
4,500,000	-	0, 1, 6, 7, 9, 10, 11, 17, 19, 24	2, 3, 4, 5, 8, 12, 13, 14, 15, 16, 18, 20, 21, 22, 23	-	66.8	4408000
5,000,000	-	1, 6, 10, 17, 19, 24	0, 2, 3, 4, 5, 7, 8, 9, 11, 12, 13, 14, 15, 16, 18, 20, 21, 22, 23	-	71.0	4901000
5,500,000	-	10, 17	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24	-	75.4	5421000
6,000,000	-	-	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24	-	78.2	5862000
6,500,000	-	-	1, 2, 3, 4, 5, 7, 8, 9, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 23, 24	0, 6, 10, 17	79.4	6367000