Assignment 1
Epidemic Modelling report

YOU CHAN LEE
s3850825@student.rmit.edu.au
Bachelor of Computer Science

• Introduction

In this report, we will evaluate our implemented structures which are adjacency list, adjacency matrix, and incidence matrix in terms of their time complexities for the different operations and different use case scenarios. In each scenario, we will consider and recommend which implementation would be most appropriate. Lastly, we will show the outcomes of SIR epidemic model simulations.

• Data and experiment setup

To evaluate our data structures, we need to generate several graphs, so we decided to use Erdos-Renyi and Scale-free graphs which are automatic graph generators. For vertex degree, we decided to use 5, 20, and 50 because each number is more than double of previous number, so we could clearly see the difference of time complexities. For number of vertices, we decided to use 100, 200, and 400 because we noticed that in scenario 2, our laptop stopped running if we have over 500 vertices. We generated 3 graphs on each vertex degree and number of vertices so total 54 graphs are used. The table below lists the graphs of Erdos-Renyi and Scale-free.

Erdos-Renyi		**Vertex degree**		
		5	20	50
Number of vertices	100	ER_V100D5_1.net ER_V100D5_2.net ER_V100D5_3.net	ER_V100D20_1.net ER_V100D20_2.net ER_V100D20_3.net	ER_V100D50_1.net ER_V100D50_2.net ER_V100D50_3.net
	200	ER_V200D5_1.net ER_V200D5_2.net ER_V200D5_3.net	ER_V200D20_1.net ER_V200D20_2.net ER_V200D20_3.net	ER_V200D50_1.net ER_V200D50_2.net ER_V200D50_3.net
	400	ER_V400D5_1.net ER_V400D5_2.net ER_V400D5_3.net	ER_V400D20_1.net ER_V400D20_2.net ER_V400D20_3.net	ER_V400D50_1.net ER_V400D50_2.net ER_V400D50_3.net

Scale-free		**Vertex degree**		
		5	20	50
Number of vertices	100	SF_V100D5_1.net SF_V100D5_2.net SF_V100D5_3.net	SF_V100D20_1.net SF_V100D20_2.net SF_V100D20_3.net	SF_V100D50_1.net SF_V100D50_2.net SF_V100D50_3.net
	200	SF_V200D5_1.net SF_V200D5_2.net SF_V200D5_3.net	SF_V200D20_1.net SF_V200D20_2.net SF_V200D20_3.net	SF_V200D50_1.net SF_V200D50_2.net SF_V200D50_3.net
	400	SF_V400D5_1.net SF_V400D5_2.net SF_V400D5_3.net	SF_V400D20_1.net SF_V400D20_2.net SF_V400D20_3.net	Sf_V400D50_1.net SF_V400D50_2.net SF_V400D50_3.net

• Use case scenarios

○ Scenario 1 k-hop Neighbourhoods

We decided to use 100 vertices for this scenario 1. The table below lists the times(seconds) of all of vertex's k-hop neighbourhoods depend on size of k in adjacency list, adjacency matrix, and incidence matrix. We used both of Erdos-Renyi and Scale-free graphs for this scenario 1.

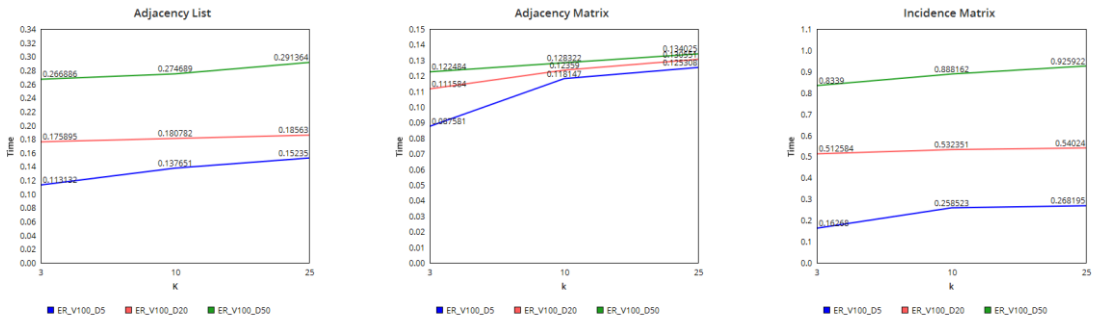
Erdos-Renyi

	Adjacency List				**Adjacency Matrix**				**Incidence Matrix**			
K	First	Second	Third	Average	First	Second	Third	Average	First	Second	Third	Average
	Degree 5				Degree 5				Degree 5			

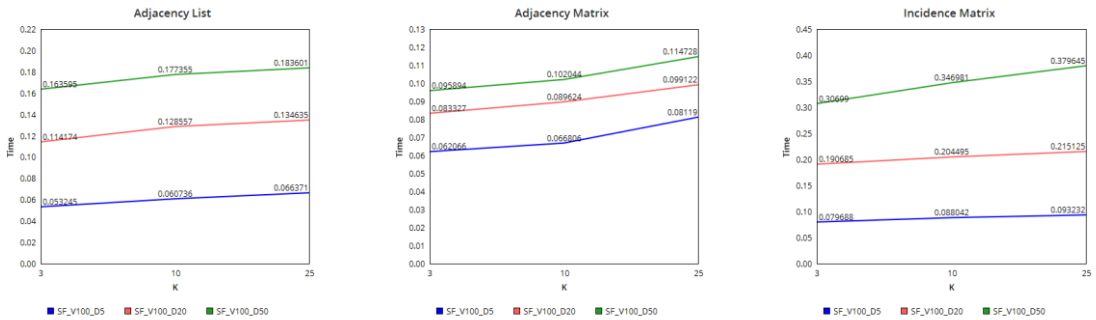
3	0.105945	0.108925	0.124525	0.113132	0.084837	0.089869	0.088036	0.087581	0.167027	0.161263	0.159749	0.16268
10	0.129712	0.145878	0.137364	0.137651	0.123017	0.116049	0.115376	0.118147	0.258946	0.258996	0.257628	0.258523
25	0.154767	0.149092	0.153192	0.15235	0.129962	0.120649	0.125314	0.125308	0.269799	0.268799	0.265986	0.268195
	Degree 20				Degree 20				Degree 20			
3	0.173594	0.179942	0.174148	0.175895	0.110774	0.108834	0.115145	0.111584	0.509809	0.514442	0.513502	0.512584
10	0.180183	0.182342	0.179822	0.180782	0.130278	0.121130	0.119361	0.12359	0.539576	0.534681	0.522795	0.532351
25	0.185209	0.188447	0.183234	0.18563	0.130952	0.132574	0.128128	0.130551	0.544079	0.535796	0.540846	0.54024
	Degree 50				Degree 50				Degree 50			
3	0.265968	0.264703	0.269987	0.266886	0.122173	0.119973	0.125307	0.122484	0.833497	0.815988	0.852216	0.8339
10	0.269983	0.276835	0.277250	0.274689	0.125672	0.129153	0.130141	0.128322	0.906098	0.864765	0.893622	0.888162
25	0.295229	0.289343	0.289521	0.291364	0.126829	0.135923	0.139324	0.134025	0.949582	0.896224	0.931961	0.925922

Scale-free

	Adjacency List				**Adjacency Matrix**				**Incidence Matrix**			
K	First	Second	Third	Average	First	Second	Third	Average	First	Second	Third	Average
	Degree 5				Degree 5				Degree 5			
3	0.051676	0.053018	0.055041	0.053245	0.057376	0.068977	0.059845	0.062066	0.077556	0.081852	0.079657	0.079688
10	0.059549	0.060125	0.062533	0.060736	0.065868	0.070605	0.063944	0.066806	0.083243	0.085906	0.094976	0.088042
25	0.063027	0.067995	0.068092	0.066371	0.099508	0.075323	0.068739	0.08119	0.088117	0.093446	0.098134	0.093232
	Degree 20				Degree 20				Degree 20			
3	0.113201	0.113527	0.115795	0.114174	0.083313	0.082175	0.084492	0.083327	0.194403	0.197976	0.179677	0.190685
10	0.131369	0.128459	0.125843	0.128557	0.088562	0.084545	0.095764	0.089624	0.210518	0.209424	0.193544	0.204495
25	0.133828	0.138044	0.132032	0.134635	0.091339	0.098799	0.107227	0.099122	0.223187	0.211119	0.211068	0.215125
	Degree 50				Degree 50				Degree 50			
3	0.166205	0.156013	0.168567	0.163595	0.099107	0.089886	0.098688	0.095894	0.306954	0.280184	0.333832	0.30699
10	0.178598	0.173632	0.179835	0.177355	0.106341	0.099161	0.100629	0.102044	0.358003	0.311036	0.371904	0.346981
25	0.181879	0.179263	0.189662	0.183601	0.113484	0.116145	0.114555	0.114728	0.403437	0.339668	0.395831	0.379645



With Erdos-Renyi graphs, we can cleary see that time increases as vertex degree and k incresases. We can also see adjacency matrix is the most efficient graph and incidence matrix is the most inefficient graph.



With Scale-free graphs, we can cleary see that time increases as vertex degree and k incresases. We can also see adjacency matrix is the most efficient graph and incidence matrix is the most inefficient graph.

○ Scenario 2 Dynamic Contact Conditions

The table below lists the times(seconds) of non-existent edge additions and existent edges deletions depend on number of vertices and vertex degree in adjacency list, adjacency matrix, and incidence matrix. We used both of Erdos-Renyi and Scale-free graphs for this scenario 2.

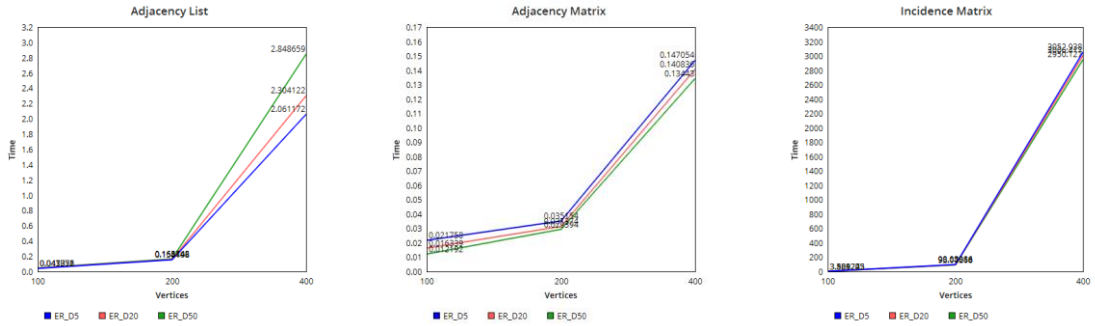
Erdos-Renyi (edge additions)

	Adjacency List				**Adjacency Matrix**				**Incidence Matrix**			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**

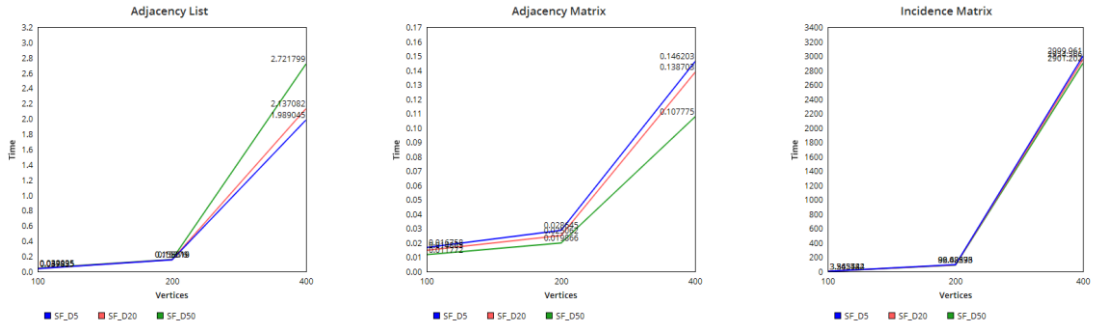
	Degree 5				Degree 5				Degree 5			
100	0.040029	0.042051	0.041132	0.041071	0.020275	0.021445	0.023556	0.021758	3.603995	3.992512	4.01123	3.869245
200	0.154132	0.161135	0.148223	0.154496	0.032213	0.035521	0.037729	0.035154	98.15533	97.33571	98.66154	98.05086
400	2.004663	2.023521	2.155332	2.061172	0.150833	0.144668	0.145663	0.147054	3053.929	3049.223	3055.663	3052.938
	Degree 20				Degree 20				Degree 20			
100	0.044023	0.040555	0.045552	0.043376	0.017162	0.015223	0.016633	0.016339	3.526291	3.475023	3.523511	3.508275
200	0.154218	0.163225	0.157003	0.158148	0.032115	0.031126	0.030882	0.031374	95.55213	94.77283	95.11203	95.14566
400	2.341528	2.315523	2.255317	2.304122	0.139422	0.142535	0.140552	0.140836	3003.223	3006.315	3009.713	3006.417
	Degree 50				Degree 50				Degree 50			
100	0.049112	0.043921	0.050223	0.047752	0.010691	0.012334	0.013552	0.012192	3.040098	3.12255	3.20096	3.121202
200	0.162153	0.165523	0.169552	0.165742	0.030552	0.029915	0.027715	0.029394	92.33851	91.88273	91.99532	92.07218
400	2.900091	2.912355	2.733532	2.848659	0.137235	0.129532	0.136523	0.13443	2952.209	2950.556	2947.617	2950.127

Scale-free (edge additions)

	Adjacency List				**Adjacency Matrix**				**Incidence Matrix**			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
	Degree 5				Degree 5				Degree 5			
100	0.036019	0.039015	0.038441	0.037825	0.019511	0.014892	0.015873	0.016758	3.512366	3.597725	3.578261	3.562784
200	0.152236	0.158823	0.150221	0.15376	0.028398	0.030186	0.027352	0.028645	96.16769	95.68264	96.22756	96.02596
400	1.969892	1.989732	2.007511	1.989045	0.147236	0.142612	0.148763	0.146203	3001.236	2998.435	3000.211	2999.961
	Degree 20				Degree 20				Degree 20			
100	0.042123	0.040216	0.036147	0.039495	0.015839	0.014162	0.014416	0.014805	3.525001	3.30016	3.211166	3.345442
200	0.156186	0.155198	0.153675	0.155019	0.025568	0.026018	0.023601	0.025062	92.58861	92.19605	92.66355	92.48273
400	2.105862	2.096632	2.208753	2.137082	0.140682	0.137856	0.137572	0.138703	2955.361	2952.981	2955.356	2954.566
	Degree 50				Degree 50				Degree 50			
100	0.045868	0.043175	0.045763	0.044935	0.011993	0.012236	0.011088	0.011772	3.398541	3.192648	3.145379	3.245522
200	0.159836	0.158752	0.156962	0.158516	0.021052	0.019965	0.018583	0.019866	89.11623	89.55816	90.37562	89.68333
400	2.736816	2.719756	2.708826	2.721799	0.106827	0.118967	0.097532	0.107775	2900.009	2901.664	2901.935	2901.202



With Erdos-Renyi graphs, we can clearly see that time increases as vertex and degree increases in adjacency list, but time increases as vertex increases and time decreases as degree increases in adjacency matrix and incidence matrix. We can also see adjacency matrix is the most efficient and incidence matrix is the most inefficient.



With Scale-free graphs, we can clearly see that time increases as vertex and degree increases in adjacency list, but time increases as vertex increases and time decreases as degree increases in adjacency matrix and incidence matrix. We can also see adjacency matrix is the most efficient and incidence matrix is the most inefficient.

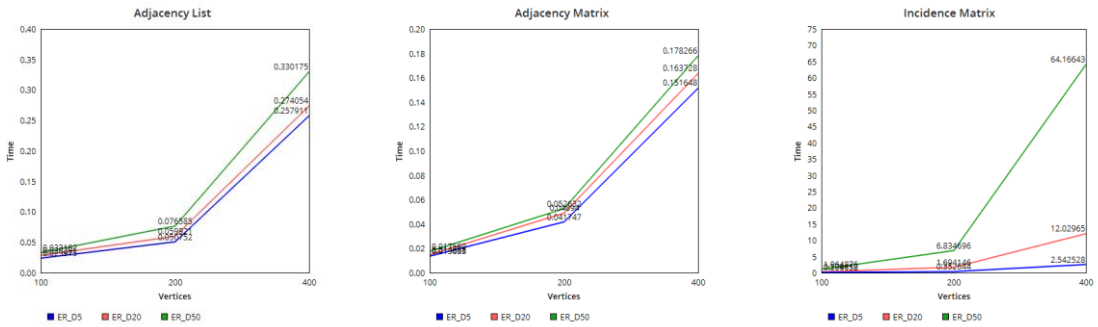
Erdos-Renyi (edge deletions)

	Adjacency List				**Adjacency Matrix**				**Incidence Matrix**			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
	Degree 5				Degree 5				Degree 5			

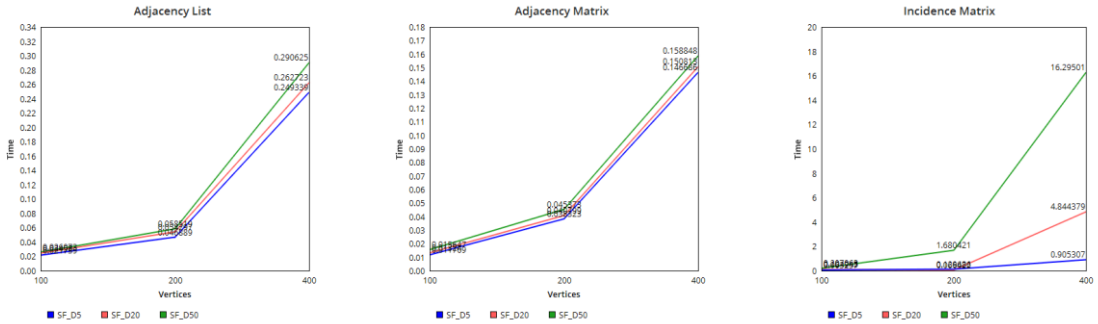
100	0.026715	0.020158	0.024872	0.023915	0.013643	0.014226	0.013032	0.013633	0.108641	0.107853	0.110862	0.109118
200	0.051132	0.050123	0.051003	0.050752	0.040238	0.045102	0.039901	0.041747	0.356918	0.349862	0.351152	0.352644
400	0.255015	0.260385	0.258331	0.257911	0.155321	0.149263	0.150362	0.151648	2.437728	2.581223	2.608635	2.542528
	Degree 20				Degree 20				Degree 20			
100	0.028192	0.027897	0.029085	0.028391	0.014763	0.014826	0.015077	0.014888	0.265847	0.276365	0.281746	0.274652
200	0.058993	0.061003	0.059766	0.059921	0.048173	0.049777	0.048871	0.048940	1.658839	1.705826	1.717775	1.694146
400	0.283452	0.269374	0.269337	0.274054	0.164335	0.161326	0.165523	0.163728	12.52632	11.55399	12.00864	12.02965
	Degree 50				Degree 50				Degree 50			
100	0.029985	0.038167	0.031156	0.033102	0.017395	0.016677	0.018636	0.017569	0.998321	1.087673	1.108635	1.064876
200	0.071773	0.077372	0.080611	0.076585	0.052237	0.050289	0.055372	0.052632	6.812352	6.836525	6.855213	6.834696
400	0.333871	0.323528	0.333127	0.330175	0.171738	0.185335	0.177727	0.178266	64.38723	64.99826	63.11382	64.16643

Scale-free (edge deletions)

	Adjacency List				Adjacency Matrix				Incidence Matrix			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
	Degree 5				Degree 5				Degree 5			
100	0.023051	0.021053	0.021113	0.021739	0.011976	0.011327	0.012005	0.011769	0.059228	0.067327	0.063216	0.063257
200	0.046923	0.046813	0.046933	0.046889	0.038922	0.039921	0.036128	0.038323	0.131892	0.127832	0.129336	0.129686
400	0.250135	0.248773	0.249111	0.249339	0.148775	0.145726	0.145558	0.146686	0.859912	0.922359	0.933651	0.905307
	Degree 20				Degree 20				Degree 20			
100	0.024634	0.025112	0.023995	0.024580	0.014155	0.012932	0.012633	0.01324	0.099239	0.102532	0.113066	0.104945
200	0.054113	0.054898	0.053882	0.054297	0.039983	0.041153	0.041262	0.040799	0.062603	0.071152	0.065512	0.066422
400	0.259332	0.265523	0.263316	0.262723	0.149555	0.150333	0.152553	0.150813	4.527381	5.022135	4.983621	4.844379
	Degree 50				Degree 50				Degree 50			
100	0.025593	0.025983	0.026643	0.026073	0.015663	0.016012	0.015266	0.015647	0.212102	0.200235	0.208853	0.207063
200	0.055113	0.059321	0.061123	0.058519	0.042733	0.044623	0.048765	0.045373	1.660552	1.677392	1.703321	1.680421
400	0.287371	0.295673	0.288831	0.290625	0.155531	0.156693	0.164321	0.158848	16.63523	15.99382	16.25599	16.29501



With Erdos-Renyi graphs, we can clearly see that time increases as vertex and degree increases. We can also see adjacency matrix is the most efficient and incidence matrix is the most inefficient.



With Scale-free graphs, we can clearly see that time increases as vertex and degree increases. We can also see adjacency matrix is the most efficient and incidence matrix is the most inefficient.

○ Scenario 3 Dynamic People Tracing

The table below lists the times(seconds) of non-existent vertex additions and existent vertex deletions depend on number of vertices and vertex degree in adjacency list, adjacency matrix, and incidence matrix. We used both of Erdos-Renyi and Scale-free graphs for this scenario 3.

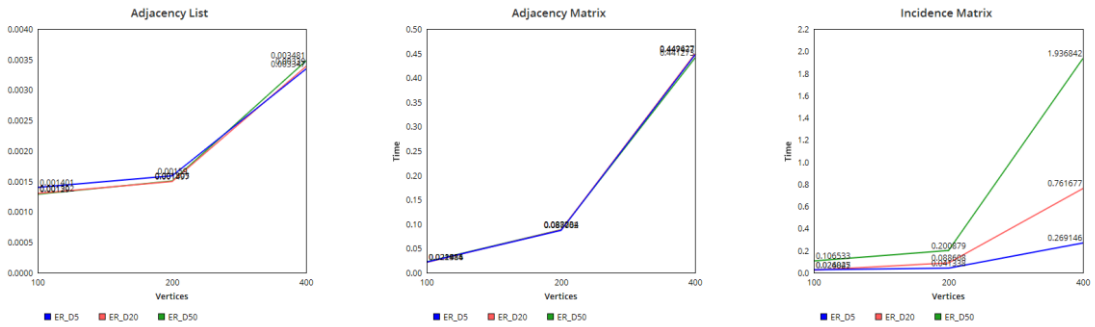
Erdos-Renyi (vertex additions)

	Adjacency List				Adjacency Matrix				Incidence Matrix			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
	Degree 5				Degree 5				Degree 5			

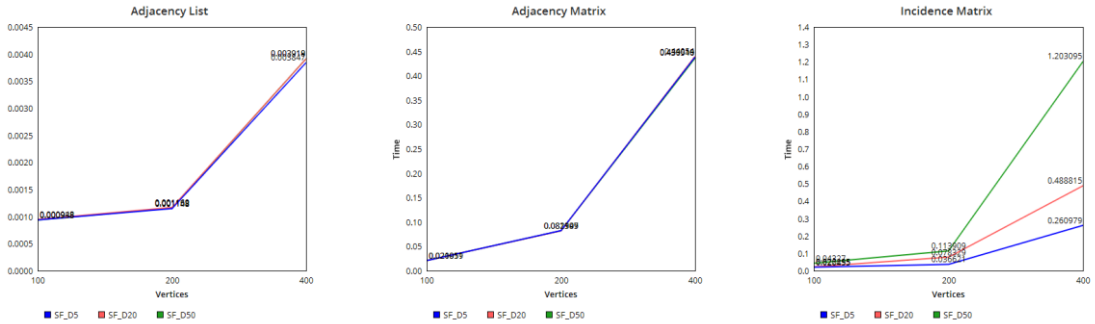
100	0.001418	0.001315	0.001471	0.001401	0.023491	0.022123	0.020331	0.021981	0.020856	0.030331	0.029355	0.026847
200	0.001573	0.001587	0.001610	0.00159	0.083455	0.086331	0.091223	0.087003	0.041345	0.041002	0.041667	0.041338
400	0.003265	0.003156	0.003621	0.003347	0.456712	0.448828	0.436891	0.447477	0.263093	0.278832	0.265513	0.269146
	Degree 20				Degree 20				Degree 20			
100	0.001053	0.001321	0.001533	0.001302	0.021393	0.022354	0.020713	0.021486	0.022353	0.025332	0.024391	0.024025
200	0.001511	0.001487	0.001495	0.001497	0.085521	0.086245	0.091522	0.087762	0.085321	0.088292	0.092211	0.088608
400	0.003116	0.003898	0.003156	0.00339	0.444019	0.445883	0.458981	0.449627	0.752391	0.723769	0.808873	0.761677
	Degree 50				Degree 50				Degree 50			
100	0.001235	0.001311	0.001326	0.001290	0.023935	0.021223	0.022385	0.022514	0.098231	0.113626	0.107742	0.106533
200	0.001493	0.001522	0.001501	0.001505	0.085992	0.083112	0.095599	0.088234	0.203341	0.199235	0.200061	0.200879
400	0.003671	0.003701	0.003072	0.003481	0.441365	0.471362	0.411092	0.441273	1.793828	2.038964	1.977736	1.936842

Scale-free (vertex additions)

	Adjacency List				Adjacency Matrix				Incidence Matrix			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
	Degree 5				Degree 5				Degree 5			
100	0.000917	0.000957	0.000941	0.000938	0.021003	0.020607	0.021125	0.020911	0.021263	0.019553	0.020551	0.020455
200	0.001146	0.001151	0.001148	0.001148	0.082115	0.083189	0.081889	0.082397	0.035291	0.037993	0.036579	0.036621
400	0.003548	0.004168	0.003827	0.003847	0.437123	0.440162	0.439772	0.439019	0.265729	0.255271	0.261937	0.260979
	Degree 20				Degree 20				Degree 20			
100	0.000926	0.000933	0.000986	0.000948	0.020514	0.021902	0.020761	0.021059	0.023185	0.022371	0.021331	0.022295
200	0.001175	0.001149	0.001183	0.001169	0.082038	0.083116	0.080682	0.081945	0.078238	0.080128	0.076621	0.078329
400	0.003827	0.003916	0.004012	0.003918	0.439816	0.441725	0.440081	0.440540	0.492731	0.482538	0.491176	0.488815
	Degree 50				Degree 50				Degree 50			
100	0.000911	0.000981	0.000923	0.000938	0.020191	0.021883	0.021077	0.021050	0.039625	0.042059	0.048128	0.043270
200	0.001152	0.001117	0.001206	0.001158	0.083168	0.081169	0.081992	0.082109	0.115612	0.106389	0.119728	0.113909
400	0.003951	0.004091	0.003716	0.003919	0.437765	0.431758	0.440117	0.436546	1.205382	1.186352	1.217553	1.203095



With Erdos-Renyi graphs, we can clearly see that time increases as vertex and degree increases in incedence matrix, but time increases as vertex increases and time remains constant as degree increases in adjacency matrix and incidence matrix. We can also see adjacency list is the most efficient and incidence matrix is the most inefficient.



With Scale-free graphs, we can clearly see that time increases as vertex and degree increases in incedence matrix, but time increases as vertex increases and time remains constant as degree increases in adjacency matrix and incidence matrix. We can also see adjacency list is the most efficient and incidence matrix is the most inefficient.

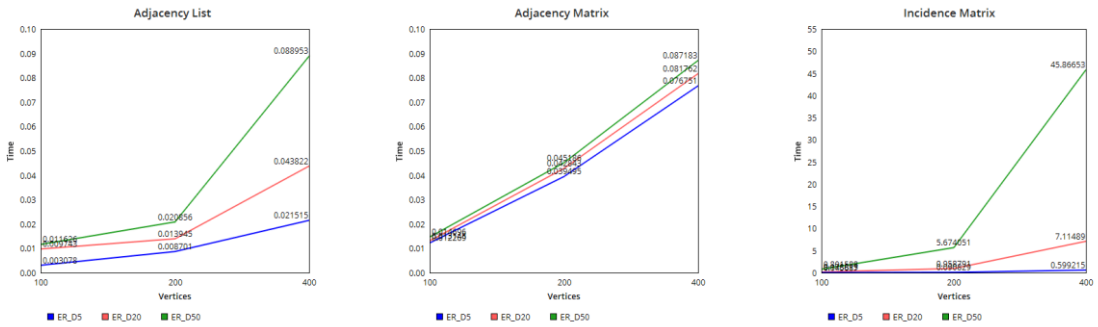
Erdos-Renyi (vertex deletions)

	Adjacency List				Adjacency Matrix				Incidence Matrix			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
	Degree 5				Degree 5				Degree 5			
100	0.003513	0.002538	0.003185	0.003078	0.010322	0.013929	0.012557	0.012269	0.044526	0.046816	0.045721	0.045687

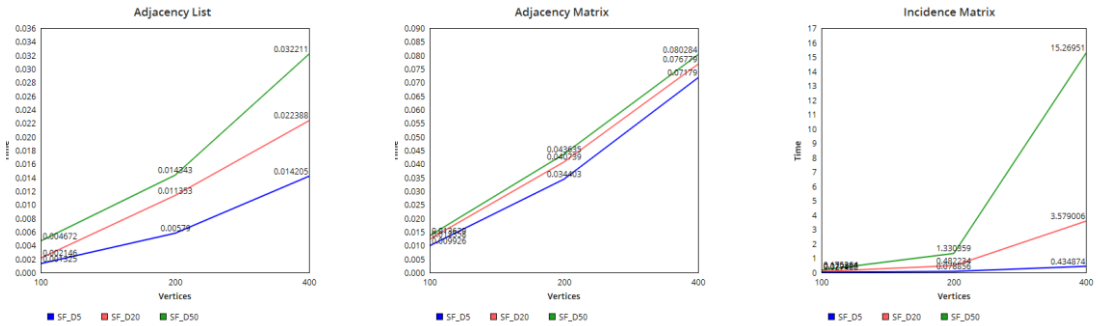
200	0.008375	0.009736	0.007993	0.008701	0.035827	0.040887	0.041773	0.039495	0.090132	0.094736	0.087619	0.090829
400	0.019836	0.020572	0.024137	0.021515	0.077734	0.077583	0.074936	0.076751	0.557287	0.608625	0.631735	0.599215
	Degree 20				Degree 20				Degree 20			
100	0.009513	0.010552	0.009166	0.009743	0.012358	0.013216	0.013872	0.013148	0.185736	0.173827	0.176882	0.178815
200	0.012957	0.014882	0.013997	0.013945	0.042876	0.043882	0.041772	0.042843	0.960283	0.967271	0.948819	0.958791
400	0.043882	0.041867	0.045717	0.043822	0.079886	0.081635	0.083765	0.081762	6.876628	7.278691	7.189352	7.114890
	Degree 50				Degree 50				Degree 50			
100	0.012258	0.011732	0.010889	0.011626	0.014882	0.014521	0.014687	0.014696	0.793856	0.824658	0.786251	0.801588
200	0.021981	0.020875	0.019714	0.020856	0.044897	0.045776	0.044886	0.045186	5.672189	5.729947	5.620017	5.674051
400	0.087583	0.087652	0.091625	0.088953	0.084527	0.089372	0.087652	0.087183	45.50827	46.21883	45.87251	45.86653

Scale-free (vertex deletions)

	Adjacency List				**Adjacency Matrix**				**Incidence Matrix**			
V	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**	**First**	**Second**	**Third**	**Average**
	Degree 5				Degree 5				Degree 5			
100	0.001161	0.001458	0.001358	0.001325	0.009251	0.009971	0.010557	0.009926	0.030238	0.027989	0.024172	0.027466
200	0.006238	0.005382	0.005751	0.005790	0.033286	0.034772	0.035152	0.034403	0.071372	0.080636	0.084561	0.078856
400	0.014836	0.013782	0.013997	0.014205	0.074192	0.071251	0.069928	0.071790	0.424838	0.442173	0.437613	0.434874
	Degree 20				Degree 20				Degree 20			
100	0.002313	0.002155	0.001972	0.002146	0.012931	0.012185	0.011959	0.012358	0.076172	0.082734	0.080726	0.079877
200	0.010327	0.011727	0.012007	0.011353	0.040581	0.039971	0.041667	0.040739	0.473816	0.483726	0.489162	0.482234
400	0.021893	0.022157	0.023115	0.022388	0.075836	0.075581	0.078921	0.076779	3.641623	3.573218	3.522178	3.579006
	Degree 50				Degree 50				Degree 50			
100	0.004957	0.004488	0.004571	0.004672	0.013896	0.013726	0.013266	0.013629	0.167382	0.176525	0.182185	0.175364
200	0.013867	0.014898	0.014266	0.014343	0.043183	0.039172	0.048551	0.043635	1.298367	1.326389	1.366321	1.330359
400	0.031258	0.032258	0.033118	0.032211	0.079112	0.081129	0.080612	0.080284	15.48762	14.99275	15.32816	15.26951



With Erdos-Renyi graphs, we can clearly see that time increases as vertex and degree increases. We can also see adjacency list is the most efficient and incidence matrix is the most inefficient.



With Scale-free graphs, we can clearly see that time increases as vertex and degree increases. We can also see adjacency list is the most efficient and incidence matrix is the most inefficient.

• SIR Model Epidemic Simulation

To evaluate what effect the parameters of graph type, infection and recover probabilities have on the spread of the epidemic in the SIR model, we decided to use ER_V200D20_1.net and SF_V200D20_1.net graphs. We also decided to use adjacency matrix and incidence matrix. The table below lists the times(seconds) of SIR model simulation.

○ Seed Initialisation

Erdos-Renyi

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	12	0.0938724
Adjacency Matrix	1;10;20;30;40;50;60	0.9	0.1	10	0.0849762
Adjacency Matrix	1;10;20	0.9	0.1	8	0.0809861

Scale-free

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	11	0.0899374
Adjacency Matrix	1;10;20;30;40;50;60	0.9	0.1	11	0.0735229
Adjacency Matrix	1;10;20	0.9	0.1	8	0.0722583

Erdos-Renyi

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	11	0.1482197
Incidence Matrix	1;10;20;30;40;50;60	0.9	0.1	10	0.1261612
Incidence Matrix	1;10;20	0.9	0.1	9	0.1108523

Scale-free

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	13	0.1062831
Incidence Matrix	1;10;20;30;40;50;60	0.9	0.1	9	0.0985572
Incidence Matrix	1;10;20	0.9	0.1	9	0.0815534

We can clearly see that time increases as number of seed initialisation increases. We can also see adjacency matrix is more efficient and scale-free graph type is more efficient.

○ Infection Probability

Erdos-Renyi

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	12	0.0938724
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.5	0.1	9	0.0888092
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.1	0.1	8	0.0811853

Scale-free

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	11	0.0899374
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.5	0.1	9	0.0847815
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.1	0.1	8	0.0707726

Erdos-Renyi

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	11	0.1482197
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.5	0.1	10	0.136763
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.1	0.1	8	0.1186552

Scale-free

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	13	0.1062831
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.5	0.1	11	0.101432
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.1	0.1	8	0.099862

We can clearly see that time increases as infection probability increases. We can also see adjacency matrix is more efficient and scale-free graph type is more efficient.

- **Recover Probability**

Erdos-Renyi

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	11	0.1482197
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.5	8	0.1160183
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.9	6	0.0967524

Scale-free

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	13	0.1062831
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.5	7	0.0711635
Adjacency Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.9	5	0.0577827

Erdos-Renyi

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	11	0.1482197
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.5	7	0.1008163
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.9	6	0.0977362

Scale-free

Data Structure	Seed Initialisation	Infection Probability	Recover Probability	Iteration	Time
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.1	13	0.1062831
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.5	7	0.0872357
Incidence Matrix	1;10;20;30;40;50;60;70;80;90;100;110;120	0.9	0.9	6	0.0716356

We can clearly see that time decreases as recover probability increases. We can also see adjacency matrix is more efficient and scale-free graph type is more efficient.

• Conclusion

To evaluate our implemented structures in terms of their time complexities for the different operations and different use case scenarios, we used Erdos-Renyi and Scale-free graph generator. In scenario 1 which is k-hop neighbourhoods, with both of Erdos-Renyi and Scale-free graph types, we can see that time increases as vertex degree and k incresases. We recommend to use adjacency matrix because it is the most efficient data structure in every aspect in terms of time complexity. In scenario 2 which is dynamic contact conditions, with both of Erdos-Renyi and Scale-free graph types, we can see that time increases as vertex and degree increases in adjacency list, but time increases as vertex increases and time decreases as degree increases in adjacency matrix and incidence matrix. We recommend to use adjacency matrix because it is the most efficient data structure in every aspect in terms of time complexity. In scenario 3 which is dynamic people tracing, with both of Erdos-Renyi and Scale-free graph types, we can see that time increases as vertex and degree increases. We recommend to use adjacency list because it is the most efficient data structure in every aspect in terms of time complexity. Lastly, in SIR model epidemic simulation, we can see that time increases as number of seed initialisation increases, infection probability increases, and recover probability decreases. We recommend to use adjacency matrix and scale-free graph type because these are the most efficient data structure in every aspect in terms of time complexity.