

Technical Note 1: Morocco GIS Data

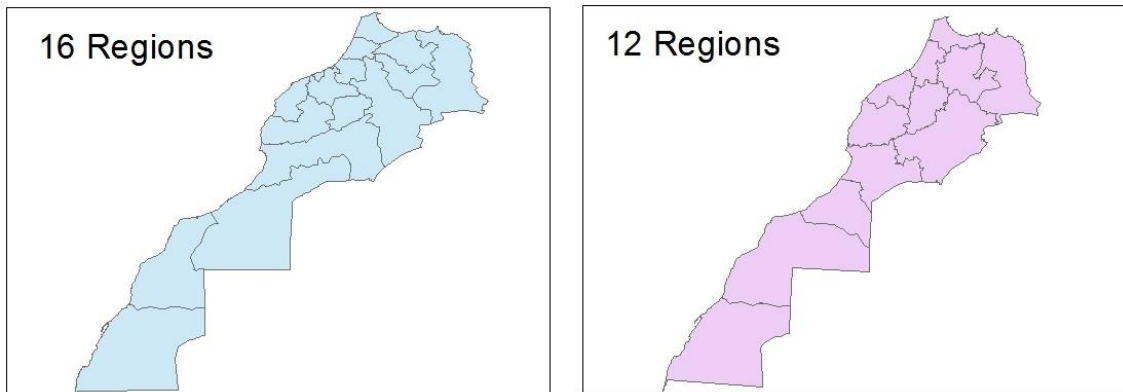
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1. Regions, Provinces and Municipalities Maps

The shape files of administrative boundaries were provided by e-mail (by AIT ALI Abdelaaziz [Abdelaaziz.AITALI@ocppc.ma]) on 16/10/2015.

The country was divided into Regions, Provinces and Municipalities. Between 1997 and 2015, Morocco was organized in 16 Regions; afterwards Morocco administers officially 12 Regions. The Figure below represents these shape files.

Morocco Regions


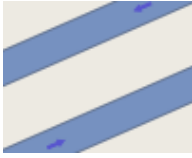


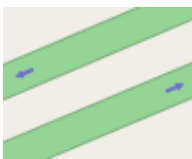





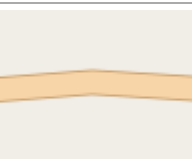













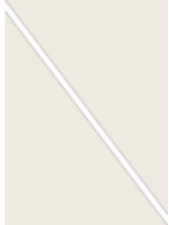

2. Road Network Map

The road network data were taken from *OpenStreetMap* (<http://www.openstreetmap.org/>). This is a free and editable map built by volunteers and released with an open-content license. The data from *OpenStreetMap* were downloaded from Geofabrik's free download server. (<http://download.geofabrik.de/index.html>).


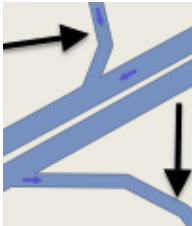


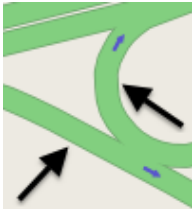





The road network in *OpenStreetMap* is classified by a tag named "highway" that is any road, route, way, or thoroughfare on land which connects one location to another and has been paved or otherwise improved to allow travel by some conveyance, including motorized vehicles, cyclists, pedestrians, horse riders, and others (but not trains). The table below (extracted from http://wiki.openstreetmap.org/wiki/Map_Features) describes how the road network is classified by the *OpenStreetMap*.

Main tags for the road network

<i>Key</i>	<i>Value</i>	<i>Element</i>	<i>Comment</i>	<i>Rendering</i>	<i>Photo</i>
highway	motorway		A restricted access major divided highway, normally with 2 or more running lanes plus emergency hard shoulder. Equivalent to the Freeway, Autobahn, etc..		
highway	trunk		The most important roads in a country's system that aren't motorways. (Need not necessarily be a divided highway).		
highway	primary		The next most important roads in a country's system. (Often link larger towns).		
highway	secondary		The next most important roads in a country's system. (Often link towns).		
highway	tertiary		The next most important roads in a country's system. (Often link smaller towns and villages).		
highway	unclassified		The least most important through roads in a country's system – i.e. minor roads of a lower classification than tertiary, but which serve a purpose other than access to properties. Often link villages and hamlets. (The word 'unclassified' is a historical artefact of the UK road system and does not mean that the classification is unknown; you can use highway=road for that).		

highway	residential		Roads which serve as an access to housing, without function of connecting settlements. Often lined with housing.		
highway	service		For access roads to, or within an industrial estate, camp site, business park, car park etc. Can be used in conjunction with <code>service=*</code> to indicate the type of usage and with <code>access=*</code> to indicate who can use it and in what circumstances.		

Link roads

highway	motorway_link		The link roads (sliproads/ramps) leading to/from a motorway from/to a motorway or lower class highway. Normally with the same motorway restrictions.		
highway	trunk_link		The link roads (sliproads/ramps) leading to/from a trunk road from/to a trunk road or lower class highway.		
highway	primary_link		The link roads (sliproads/ramps) leading to/from a primary road from/to a primary road or lower class highway.		
highway	secondary_link		The link roads (sliproads/ramps) leading to/from a secondary road from/to a secondary road or lower class highway.	same rendering as highway=secondary in mapnik	
highway	tertiary_link		The link roads (sliproads/ramps) leading to/from a tertiary road from/to a tertiary road or lower class highway.	same rendering as highway=tertiary in mapnik	

For this project we considered only the main highways of the country, so we applied a filter and used the key “highway” classified as motorway, motorway_link, trunk, trunk_link, primary, primary_link, secondary, secondary_link, tertiary and tertiary_link.

The Geographic coordinate system used is the “Merchich_Sahara_Nord”.

Using the Calculate Geometry tool from ArcGis we created and calculated a new table field with the length of the roads. We also created a new table field of the average speed of the road, for this, we used the conditions showed in the table below (we need to validate the values used for the attributes).

Road type	avg speed (km/h)
motorway/motorway_link	100
trunk/trunk_link	90
primary/primary_link	80
secondary/secondary_link	60
tertiary/tertiary_link	60

With these two fields we were able to create a new field that contains the time in minutes necessary to drive the whole road length. Using the formula:

$$\text{Time (Minutes)} = \text{Length (km)} / \text{Avg speed (km/h)} * 60.$$

3. Provinces – Point Map

The point shape file for the Provinces was created using the Table below. The Longitude and Latitude coordinates from the Provinces were taken from the website <http://www.getamap.org/>.

<i>Region</i>	<i>Province</i>	<i>Longitude</i>	<i>Latitude</i>
Oued Ed Dahab-Lagouira	Oued Ed-Dahab	-13,508	23,3225
Laayoune-Boujdour-Sakia El Hamra	Laayoune	-13,195	27,1545
Laayoune-Boujdour-Sakia El Hamra	Boujdour	-14,484	26,1272
Guélmim-Es Semara	Tata	-7,9696	29,7463
Guélmim-Es Semara	Guélmim	-10,057	28,9863
Guélmim-Es Semara	Es Semara	-11,664	26,7435
Guélmim-Es Semara	Tan Tan	-11,098	28,4375
Souss-Massa-Draâ	Chtouka Ait Baha	-9,3383	30,0085
Souss-Massa-Draâ	Agadir Ida Ou Tanane	-9,585	30,4218
Souss-Massa-Draâ	Inezgane Ait Melloul	-9,5032	30,3486
Souss-Massa-Draâ	Taroudannt	-8,8779	30,4706
Souss-Massa-Draâ	Tiznit	-9,7312	29,6986
Souss-Massa-Draâ	Zagora	-5,8371	30,328
Souss-Massa-Draâ	Ouarzazate	-6,9018	30,9206
Gharb-Cherarda-Béni Hssen	Kénitra	-6,5701	34,2645
Gharb-Cherarda-Béni Hssen	Sidi Kacem	-5,7114	34,2264
Chaouia-Ouardigha	Settat	-7,6198	33,0023
Chaouia-Ouardigha	Khouribga	-6,9092	32,8855
Chaouia-Ouardigha	Benslimane	-7,1267	33,6228
Marrakech-Tensift-Al Haouz	Al Haouz	-7,9245	31,2806
Marrakech-Tensift-Al Haouz	El Kelaa Des Sraghna	-7,4067	32,0543
Marrakech-Tensift-Al Haouz	Marrakech	-7,9886	31,6259
Marrakech-Tensift-Al Haouz	Chichaoua	-8,7595	31,5469
Marrakech-Tensift-Al Haouz	Essaouira	-9,7621	31,5117
Oriental	Berkane	-2,3294	34,9266
Oriental	Nador	-2,9282	35,1792
Oriental	Oujda-Angad	-2,0358	34,6694
Oriental	Taourirt	-2,8938	34,4134
Oriental	Figuig	-1,2304	32,115
Oriental	Jerada	-2,1599	34,3105
Grand-Casablanca	Casablanca	-7,6176	33,5939
Grand-Casablanca	Mohammadia	-7,3893	33,6958
Grand-Casablanca	Nouaceur	-7,6301	33,4302
Grand-Casablanca	Médiouna	-7,5194	33,4562
Rabat-Salé-Zemmour-Zaér	Rabat	-6,839	34,0223
Rabat-Salé-Zemmour-Zaér	Salé	-6,814	34,0448
Rabat-Salé-Zemmour-Zaér	Skhirate-Témara	-6,8822	33,7538

Rabat-Salé-Zemmour-Zaér	Khémisset	-6,2648	33,6657
Doukala-Abda	El Jadida	-8,4988	33,2429
Doukala-Abda	Safi	-9,2395	32,2994
Tadla-Azilal	Béni Mellal	-6,3533	32,3341
Tadla-Azilal	Azilal	-6,5709	31,9592
Méknès-Tafilalet	El Hajeb	-5,3719	33,6901
Méknès-Tafilalet	Ifrane	-5,1074	33,5276
Méknès-Tafilalet	Errachidia	-4,4335	31,9292
Méknès-Tafilalet	Khénifra	-5,6695	32,9357
Méknès-Tafilalet	Méknès	-5,5678	33,885
Fès-Boulemane	Fès	-5,0133	34,0341
Fès-Boulemane	Sefrou	-4,8333	33,8248
Fès-Boulemane	Boulemane	-4,73	33,3659
Fès-Boulemane	Moulay Yacoub	-5,1794	34,0874
Taza-Al Hoceima-Taounate	Taza	-4,0101	34,2301
Taza-Al Hoceima-Taounate	Al Hoceima	-3,9301	35,2451
Taza-Al Hoceima-Taounate	Taounate	-4,6359	34,5384
Tanger-Tétouan	Larache	-6,1529	35,1952
Tanger-Tétouan	Tanger-Assilah	-5,8038	35,7769
Tanger-Tétouan	Chefchaouen	-5,2683	35,1687
Tanger-Tétouan	Tétouan	-5,3743	35,5705
Tanger-Tétouan	Fahs Anjra	-5,6032	35,7514

4. OD Cost Matrix

To create an Origin-Destination cost matrix we used the extension Network Analyst extension from ArcGIS. The tutorial is available on:

<http://help.arcgis.com/en/arcgisdesktop/10.0/pdf/network-analyst-tutorial.pdf>.

The parameter used to build the OD Cost Matrix were route length (kilometers) and time (minutes). On the software we can choose the shortest or the fastest route.

We used all the provinces as Origins and as Destinations points. We considered that the vehicles can drive in both directions (two-way) on the roads, so the same distance and time will be found from a point A to B and from B to A.

The following tables and figures present the estimates of distance and minimum travel time between origin-destination pairs (we have considered, for illustrative purposes, only the regional capitals). We compare the estimates based on our calibrated network and those calculated using Google Maps. Notice that the distance estimates are very close to those obtained using Google Maps. There is a small difference, nonetheless, when we compare travel time between regional capitals. It is important at this point to possibly review and validate the speed parameters used to calibrate the network!

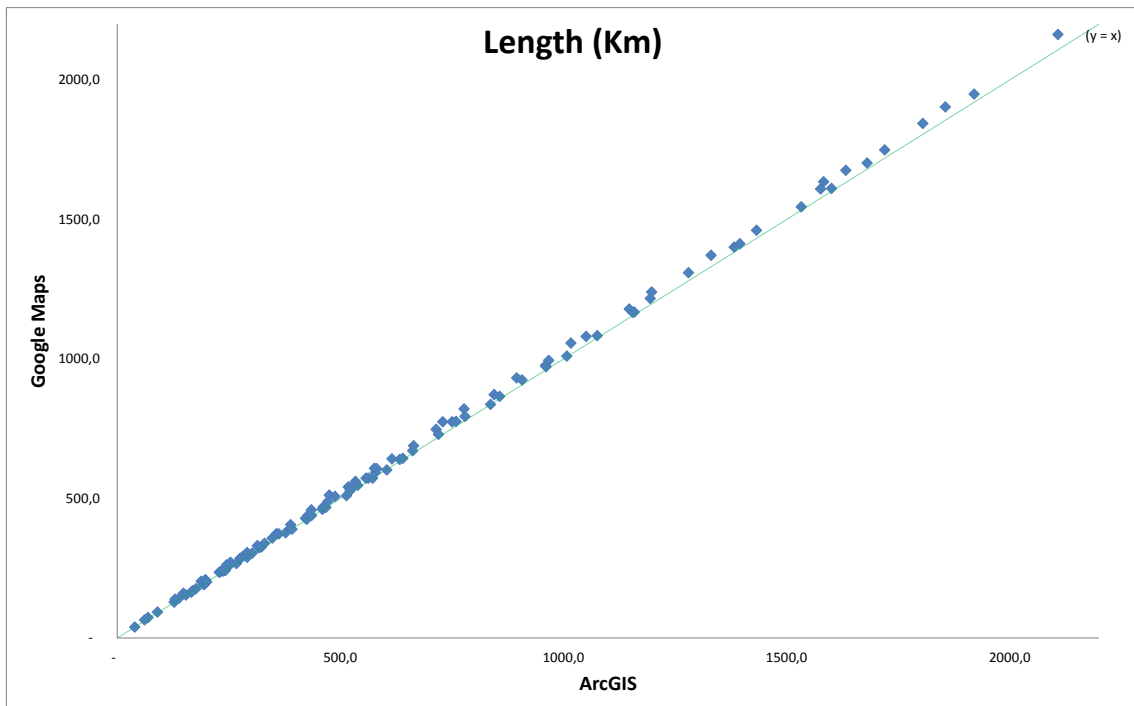
Matrix of distances between origin-destination pairs – estimation based on the calibrate GIS database for Morocco (in km)

		DESTINATION															
		Agadir	Al Hoceima	Béni Mellal	Casablanca	Dakhla	Fès	Guelmim	Kenitra	Laÿoune	Marrakech	Meknès	Oujda	Rabat	Safi	Settat	Tanger
ORIGIN	Agadir	0	967	435	460	1159	715	198	579	634	241	664	1017	540	292	392	779
	Al Hoceima	967	0	534	538	2108	254	1148	389	1583	730	314	243	428	751	577	292
	Béni Mellal	435	524	0	198	1577	280	616	267	1051	196	246	582	232	303	166	468
	Casablanca	460	518	198	0	1601	289	641	130	1076	238	229	604	90	234	69	330
	Dakhla	1159	2108	1577	1601	0	1856	961	1720	525	1383	1806	2158	1681	1433	1533	1921
	Fès	715	254	280	289	1856	0	896	176	1331	475	62	318	199	522	348	275
	Guelmim	198	1148	616	641	961	896	0	760	436	422	845	1198	720	472	573	960
	Kenitra	579	389	267	130	1720	176	760	0	1195	357	128	489	40	363	188	201
	Laÿoune	634	1583	1051	1076	525	1331	436	1195	0	857	1280	1633	1155	908	1008	1395
	Marrakech	241	730	196	238	1383	475	422	357	857	0	425	777	318	155	169	558
	Meknès	664	314	246	229	1806	62	845	128	1280	425	0	378	139	461	287	252
	Oujda	1017	243	582	604	2158	318	1198	489	1633	777	378	0	514	837	662	520
	Rabat	540	428	232	90	1681	199	720	40	1155	318	139	514	0	323	149	240
	Safi	292	751	303	234	1433	522	472	363	908	155	461	837	323	0	192	563
	Settat	392	577	166	69	1533	348	573	188	1008	169	287	662	149	192	0	389
Tanger	779	292	468	330	1921	275	960	201	1395	558	252	520	240	563	389	0	

Matrix of distances between origin-destination pairs – estimation based on Google Maps (in km)

		DESTINATION															
		Agadir	Al Hoceima	Béni Mellal	Casablanca	Dakhla	Fès	Guelmim	Kenitra	Laÿoune	Marrakech	Meknès	Oujda	Rabat	Safi	Settat	Tanger
ORIGIN	Agadir	0	995	459	461	1168	748	199	593	640	246	689	1057	547	306	390	794
	Al Hoceima	995	0	561	541	2163	271	1179	393	1635	775	331	242	440	775	608	289
	Béni Mellal	459	561	0	209	1609	290	642	267	1081	192	262	607	238	304	164	468
	Casablanca	461	541	209	0	1611	293	644	139	1083	240	235	602	93	240	73	339
	Dakhla	1168	2163	1609	1611	0	1903	972	1749	537	1401	1844	2212	1702	1461	1545	1949
	Fès	748	271	290	293	1903	0	932	176	1371	512	65	323	201	528	358	284
	Guelmim	199	1179	642	644	972	932	0	776	439	429	872	1240	730	489	573	977
	Kenitra	593	393	267	139	1749	176	776	0	1217	374	128	507	39	373	203	201
	Laÿoune	640	1635	1081	1083	537	1371	439	1217	0	866	1309	1676	1167	925	1010	1413
	Marrakech	246	775	192	240	1401	512	429	374	866	0	425	821	326	154	169	573
	Meknès	689	331	262	235	1844	65	872	128	1309	425	0	377	142	469	298	261
	Oujda	1057	242	607	602	2212	323	1240	507	1676	821	377	0	510	837	671	540
	Rabat	547	440	238	93	1702	201	730	39	1167	326	142	510	0	326	160	247
	Safi	306	775	304	240	1461	528	489	373	925	154	469	837	326	0	193	573
	Settat	390	608	164	73	1545	358	573	203	1010	169	298	671	160	193	0	406
Tanger	794	289	468	339	1949	284	977	201	1413	573	261	540	247	573	406	0	

Comparison between estimates based on the calibrated network and Google Maps



Matrix of minimum time between origin-destination pairs – estimation based on the calibrate GIS database for Morocco (in min)

ORIGIN	DESTINATION															
	Agadir	Al Hoceima	Béni Mellal	Casablanca	Dakhla	Fès	Guelmim	Kenitra	Laâyoune	Marrakech	Meknès	Oujda	Rabat	Safi	Settat	Tanger
Agadir	0	725	298	287	875	550	155	367	481	199	541	698	338	230	240	507
Al Hoceima	725	0	450	446	1584	197	864	358	1190	595	244	197	387	653	485	213
Béni Mellal	298	450	0	163	1157	253	437	229	763	146	215	401	207	274	161	369
Casablanca	287	446	163	0	1147	213	427	88	753	175	163	370	60	217	48	228
Dakhla	875	1584	1157	1147	0	1409	721	1226	394	1059	1401	1557	1198	1090	1100	1366
Fès	550	197	253	213	1409	0	689	129	1015	398	51	198	153	423	254	243
Guelmim	155	864	437	427	721	689	0	506	327	338	680	837	477	369	380	646
Kenitra	367	358	229	88	1226	129	506	0	833	254	106	360	29	296	128	140
Laâyoune	481	1190	763	753	394	1015	327	833	0	665	1007	1163	804	696	706	972
Marrakech	199	595	146	175	1059	398	338	254	665	0	389	546	225	142	127	394
Meknès	541	244	215	163	1401	51	680	106	1007	389	0	245	104	373	205	218
Oujda	698	197	401	370	1557	198	837	360	1163	546	245	0	311	580	412	401
Rabat	338	387	207	60	1198	153	477	29	804	225	104	311	0	267	99	169
Safi	230	653	274	217	1090	423	369	296	696	142	373	580	267	0	192	435
Settat	240	485	161	48	1100	254	380	128	706	127	205	412	99	192	0	267
Tanger	507	213	369	228	1366	243	646	140	972	394	218	401	169	435	267	0

Matrix of minimum time between origin-destination pairs – estimation based on Google Maps (in min)

ORIGIN	DESTINATION															
	Agadir	Al Hoceima	Béni Mellal	Casablanca	Dakhla	Fès	Guelmim	Kenitra	Laâyoune	Marrakech	Meknès	Oujda	Rabat	Safi	Settat	Tanger
Agadir	0	657	324	290	874	469	194	369	514	180	433	634	334	228	235	486
Al Hoceima	657	0	459	402	1500	233	835	335	1157	552	258	222	338	569	443	286
Béni Mellal	324	459	0	153	1164	259	481	219	803	177	228	425	199	262	136	341
Casablanca	290	402	153	0	1135	206	451	113	773	170	174	371	81	203	72	240
Dakhla	874	1500	1164	1135	0	1304	694	1214	383	1018	1273	1440	1180	1072	1080	1338
Fès	469	233	259	206	1304	0	626	134	948	347	57	198	141	378	249	261
Guelmim	194	835	481	451	694	626	0	523	325	583	335	583	782	489	381	644
Kenitra	369	335	219	113	1214	134	523	0	850	252	104	301	49	283	153	137
Laâyoune	514	1157	803	773	383	948	325	850	0	649	908	1107	819	698	718	965
Marrakech	180	552	177	170	1018	347	335	252	649	0	310	506	218	147	114	376
Meknès	433	258	228	174	1273	57	583	104	908	310	0	221	108	343	214	228
Oujda	634	222	425	371	1440	198	782	301	1107	506	221	0	304	543	414	420
Rabat	334	338	199	81	1180	141	489	49	819	218	108	304	0	247	117	173
Safi	228	569	262	203	1072	378	381	283	698	147	343	543	247	0	169	417
Settat	235	443	136	72	1080	249	389	153	718	114	214	414	117	169	0	276
Tanger	486	286	341	240	1338	261	644	137	965	376	228	420	173	417	276	0

Comparison between estimates based on the calibrated network and Google Maps

