SOP for importing realistic road distances and travel times into OptiDx for DNO analysis.

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Picture from Pexels.com

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2. **Acknowledgements**

We would like to thank Mayank Pandey and Heidi Albert for helping to write and review this SOP.

3. **Target audience**

This guide provides a step-by-step tutorial on how to gather data, calculate the road distances and travel times between health facilities using AccessMod ver. 5[1], and import the results in OptiDx[2] for users performing a DNO analysis at regional, national, or sub-national scale.

This guide is intended for users performing DNO analysis with OptiDx tool and wishing to use more realistic road distances and travel times in the analysis. Some knowledge in GIS and data manipulation is required. It is assumed that user already have some knowledge about AccessMod, or that they will acquire it in parallel to this SOP by referring to the AccessMod User Guide available from its website[3].

4. **Overall methodology**

This document describes a step-by-step process on how to incorporate road-distances calculated with AccessMod in OptiDx. OptiDx usually calculates the referral distances and travel times based on the straight-line between the sources and the destinations, corrected using a circuity factor which is calculated at a country scale (Albert et al., 2020). The use of road-distances instead of straight-line distances can be useful when some barriers to movement are present (such as rivers, lakes, …) as travel distances differences between the two can then be high (Boscoe et al., 2012). Road-distances are also useful in mountainous areas where circuity (the property of a road to not be in a straight-line) tends to increase (Kweon, 2019). Therefore, in some cases, the use of road distances can allow more realistic calculation of travel time and distances in the context of Diagnostic Network Optimization.

The data, sources and software requirements for the process are listed in this SOP. The processes consist in several steps (an overview can be found in Figure 1): First, the necessary spatial layers must be obtained, modified, and imported in AccessMod. In our example below, transportation occurred only on roads and the road layer must be modified to reflect this. Moreover, a separate layer must be created for the health facilities that are "sources" of the referrals and another for the "destinations" of the referrals. Secondly, the Referral module of AccessMod must be used to calculate the travel distances and travel times between each "sources"/" destination" pairs. Thirdly, the results must be extracted from AccessMod and a referral table similar to the one used by OptiDx must be created. This table can then be imported in OptiDx, and the DNO analysis can be launched to get the results.

Note: AccessMod can also be used to calculate travel times and distances when transportation can occur off road. If that is the case, the road network doesn't need to be modified and an according speed must be given to every type of landcover (instead of a speed of 0).
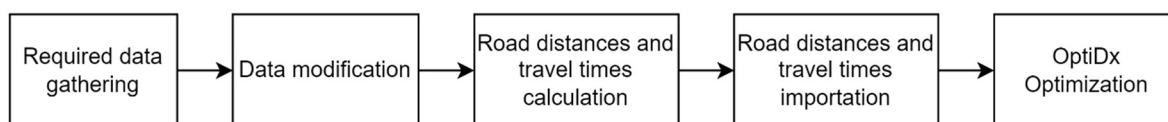
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[1] https://www.accessmod.org/
[2] https://www.optidx.org/
[3] https://owncloud.unepgrid.ch/index.php/s/DSWRvM7fic65NVf

Figure 1: Overview of the process

5. **Requirements**

a) Data requirements

The required data are the following:

Data type	Description	Preferred source	Secondary source	Added explanatory comments	Required to use AccessMod	Required to use the Network Analyst
Digital Elevation Model	Raster of the elevation.	Digital Elevation Model designed and obtained from country experts.	SRTM[1] (Free open access).	In AccessMod, the DEM is used to compute slopes that are used to correct walking and bicycling speed (if any).	**Yes.**	No
Landcover	Raster of the landcover.	Landcover raster designed and obtained from country experts.	Copernicus 2019[2] (Free open access).	In AccessMod, this raster informs about travel constraints outside of the road network and is needed to create the essential Landcover merged layer.	**Yes.**	No
Natural barriers	One or several vector layers of the natural barriers.	Specific layers obtained from partners in the country.	OpenStreet Map[3] (Free open access).	In AccessMod, this (these) layer(s) are typically the lakes, rivers and other natural barriers to movement that would be relevant to the analysis.	No.	No.
Roads	Vector of the roads.	Layers obtained from the country of interest.	OpenStreet Map[1] (Free open access).	The road layer also contains the type of road associated with each segment.	**Yes.**	**Yes.**
Health services	Vector of the health services.	This layer must be what has been assembled to conduct the DNO analysis with OptiDx.	None.	This layer must contain the name, geographic coordinates (longitude and latitude) of all health services, such as facilities, labs and hubs relevant to the analysis. The coordinates can be extracted from data nearby in OptiDx, either from the data template, or in the "add a new health facility" tab in OptiDx. This shapefile must be separated	**Yes.**	**Yes.**

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[1] https://www2.jpl.nasa.gov/srtm/
[2] https://land.copernicus.eu/global/products/lc
[3] https://www.openstreetmap.org/#map=7/20.262/87.116&layers=T

				in two shapefiles: the "sources" and the "destinations" (more information can be found in section 6).		
Travel scenario	Table of the speed of the samples for each landcover type and road type.	Discussion with local experts.	Literature search (for African countries, see Hierink et al., 2022).	Ideally, it is recommended to seek expert knowledge by discussing with local experts through dedicated workshops. If seeking local expert knowledge is not possible, the literature can be searched for studies that have estimated these values (for all African countries, see Hierink et al., 2022)	**Yes.**	**Yes.**
Landcover table	Table containing an integer code and name for each pixel value of the landcover categories.	If the landcover table was obtained with local partners, the landcover table should be obtained from the same.	Source of the landcover raster (for Copernicus, see the Copernicus 2019 User manual[1])	--	**Yes.**	**Yes.**

Table 1: Data required for the referral analysis of AccessMod

b) Software requirements

- GIS software (here we used QGIS (QGIS Association, 2022)).
- Data management software (here we used R (R Core Team, 2017)).
- Table management software (here we used Excel (Microsoft Corporation, 2018)).
- In case AccessMod is used: AccessMod 5.7 (Ray & Ebener, 2022). Ensure you have the latest version by updating directly from AccessMod (refer to AccessMod user guide to do that).

c) Specific case of our example analysis

In our example analysis, transportation only occurred on roads and therefore:

- Road network had to be modified to ensure that each health facility was located on a road segment. For this purpose, new road segments had to be created.
- In the travel scenario, off-road speeds were set artificially to 0. This ensures that AccessMod will prevent referral calculations off-roads even on long road travels with deviations. If the road network is incomplete (if some health facilities are located on roads disconnected from the main network), the calculation in AccessMod will result in an error. If transportation can occur off road, an appropriate travel speed must be given to each landcover class in this table.

6. Data preparation

a) Health services shapefiles creation

All health services must be imported as point shapefile. To do so, two ".csv" tables containing the longitudes and latitudes of **all the health facilities** must be created first. One of the tables must contain the health facilities acting as "sources", and the other one must contain the health facilities acting as

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[1] https://land.copernicus.eu/global/sites/cgls.vito.be/files/products/CGLOPS1_PUM_LC100m-V3_I3.4.pdf

"destinations". These tables must then be imported in the GIS software and two separate shapefile layers must be created. One additional shapefile containing all the sources and the destinations must be created, this "sources_and_destinations" layer will be used for missing roads creation.

b) <u>AccessMod data formatting and modifications</u>

Section 2 above mentioned the data need in AccessMod. Details about formatting these data sets and important them into AccessMod are found in the AccessMod User guide (Ray et al., 2019). The key formatting steps are to ensure that all required layers be projected using the same CRS in a metric system, with raster data sets having the exact same spatial resolution.

c) <u>Missing roads creation</u>

Road data are often incomplete and therefore can create substantial, unrealistic differences in travel times and travel distances in the context of accessibility to health facilities. More specifically, health services are often not located on roads, despite diagnostic samples usually travelling on roads only. To remove this bias, virtual road segments can be added between each health service and the closest road (Figure 2, below).

Note: This step is not necessary if transportation can also occur off road.

<u>Figure 2:</u> Addition of a new virtual road segment to an existing incomplete road network.

In order to do this, several steps have to be followed:

*1. **Closest point calculations***

The closest points from the health facilities that are on a road must be calculated. These can be done using the "Closest Points" plugin (Jung, 2020).

After installing the plugin, the user can use its functionality called "Find Closest Point for Each Feature". The "Layer to calculate closest points from" must be the layer containing all the health services (the "sources_and_destinations" layer) and the "Layer to calculate closest points to" must be the road layer.

*2. **New Roads creation***

A multi-lines polygons shapefile can now be created between these "closest points" and the health facilities using the "Distance to nearest hub (line to hub)" function in QGIS (QGIS Association, 2022).
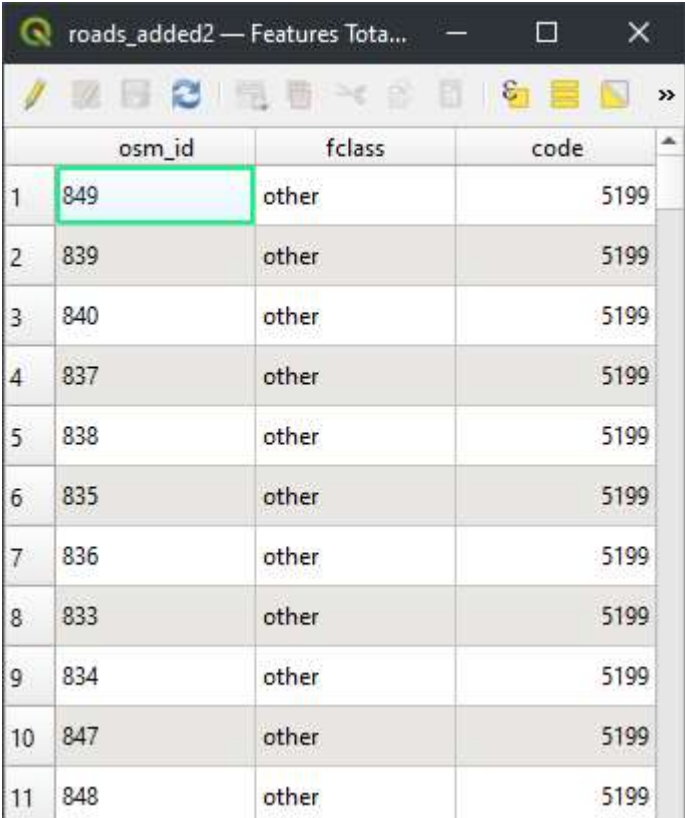
The "Source points layer" must be the "closest points" layer and the "Destinations hubs layer" must be the health services layer. The two other scrolling menus can have any value.

The resulting line layer will be the virtual road segments layer.

3. New Roads shapefile modification

The newly created road shapefile must be modified to have a similar structure to the original road shapefile. More specifically, AccessMod requires a label column (containing the class name of each road segment) and a code column (containing a unique identifier for each label). To avoid any problem, it is also advised to add a unique ID to each road segment.

Here, we used R to give a unique ID to each segment (1,2, 3…) under a new attribute table column named "osm_id", we added the "other" category to each road segment, and gave a category code of "5199" to it, which looks like this in the shapefile attribute table:

osm_id	fclass	code
1	849	other	5199
2	839	other	5199
3	840	other	5199
4	837	other	5199
5	838	other	5199
6	835	other	5199
7	836	other	5199
8	833	other	5199
9	834	other	5199
10	847	other	5199
11	848	other	5199

Figure 3: Shapefile attribute table of the added roads layer.

4. Merging of the two roads shapefiles

The newly created road shapefile can now be merged with the original road shapefile. In that case, we used the "Merge vector layers" tool in QGIS (QGIS Association, 2022).

After merging, it is necessary to check whether there is a column in the shapefile data that contains the label and code for all roads (original roads and newly created road segments). It often happens that during merging, the labels and code columns differ between the virtual road layer and the original road layer. In our case, this was done, using R. It is also necessary to check whether every road has a unique ID.

The attribute table of the final merged road layer should look like this:

Figure 4: Shapefile attribute table of the final merged road layer

7. **AccessMod analysis and export**

The AccessMod referral analysis can now be performed. The major steps in AccessMod are the following:

a) In the settings, ensure that "Show advanced settings" is checked and the "Temporary limit for data import" must be set to sufficiently large value if your data sets are large.
b) A new project must be created. To do so, the user must go to the "project" tab, enter a name for the project and upload the dem raster.
c) All data listed in "a) Data requirements" must be imported, given the required type and a tag.
d) The merge landcover must be done using the "Toolbox" tool "Merge land cover", using the staking functionality of the tool to merge the roads, barriers and landcover.
e) The layers are typically stacked in this order, from top to bottom: roads, lakes, rivers, other possible barriers, landcover, if crossing rivers using existing functional bridges is to be considered possible.

If crossing rivers is to be considered impossible, this stacking order can be used: lakes, rivers, roads, other possible barriers, and landcover.

f) The user can then do a referral analysis using the "Referral" module.
g) The appropriate input layers must be set for each scrolling menu.
h) The settings must be set as follows:
    1. "Isotropic" can be selected if there are only motorized modes of transport in the travel scenario. If transportation by foot is to be considered, "Anisotropic" can be selected to factor in the elevation in the travel time.
    2. Permute groups can be set to OFF or ON. This depends on the nature of your analysis, see the user guide for AccessMod (Ray et al., 2019). If you are not sure, leave it OFF.
    3. Enable parallelization must be ON. This allows the use of each available CPU for increased performance. Note: the user must ensure that enough RAM is available, because adding CPUs also increases the amount of used RAM. If that is not the case, this parameter should be set to OFF. See the user guide for AccessMod for details.
    4. Output the layer of the paths among selected facilities must be OFF (unless you want to visualize all computed least cost paths).
    5. Limit the spatial analysis to the closest pair timewise must be OFF.
    6. Snap the source and destination points to the grid must be ON.
    7. Maximum travel time must be set to 0 (i.e., no maximum travel time).
i) The analysis can now be launched.

More precise and detailed instructions can be found in the AccessMod User guide (Ray et al., 2019).

After the analysis is performed, the referral table (suffixed "table_referral_") can be exported. This table contains the road distances and travel times between the chosen "source" health facilities and "destination" health facilities.

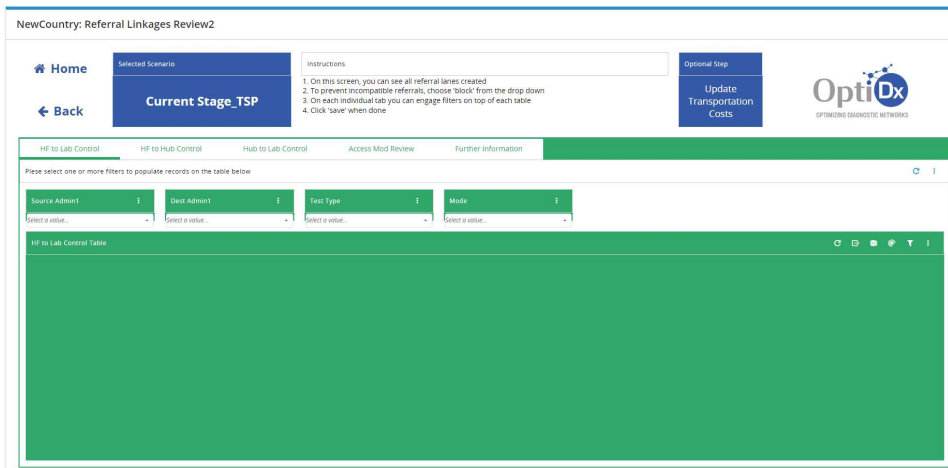There are then two possibilities:

- <u>If the user is creating a new country:</u>
  (Note: the steps to follow in the new Workcenter based approach version can be found in Annex 4)
  In that case, the user must follow every step that are required in OptiDx, until the referrals are created (in step "8. Referral Linkages" when the screen "Manage Individual Referral Linkages" is displayed). A short walkthrough of the Referral Linkages creation step can be found in Annex 1. After the referrals are created, the user should enter the "AccessMod Review" tab and press the "Export to Excel" button. The table can then be downloaded and obtained by email. Screenshots of this last process can be seen below.

  Because of current limitations in OptiDx, there referrals cannot be exported if the number of rows in the table is higher than **1 million lines**. A few recommendations to decrease the number of rows can be found in the Annex 2.

  (Optional): If the referrals have already been created, OptiDx allows the user to modify individual referrals using this button:
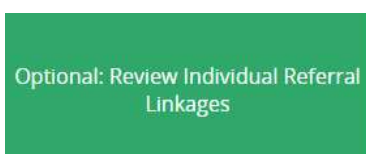
Pressing this button, will open a screen similar to the "Manage Individual Referral linkages" one:


- <u>If the user is creating a new scenario:</u>
  (Note: the steps to follow in the new Workcenter based approach version can be found in Annex 4)
  The next step is to download the current straight-line distances and travel times tables from your scenario in OptiDx. Because of current limitations in OptiDx, this table must have less than **1 million** rows, otherwise it will not be exported. Some recommendations to decrease the number of rows can be found in the Annex 2. After creating the new scenario, the user should go to "Manage Individual Referral Linkages". Then, the user can access the "AccessMod Review" tab and press "Export to Excel". The table can then be downloaded and obtained by email. Screenshots of this last process can be seen below.

In both cases, the "AccessMod Review" tab can be accessed at the following location (circled in red):
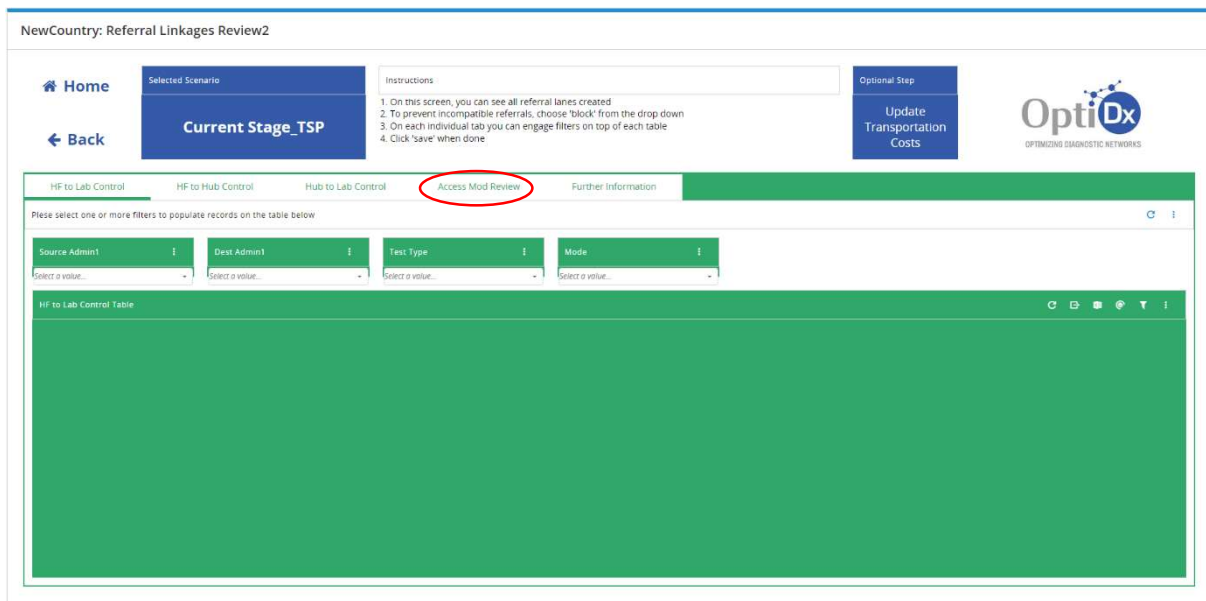
Then, the user can either "Export to Excel" or "Import to Excel" (both circled in red).
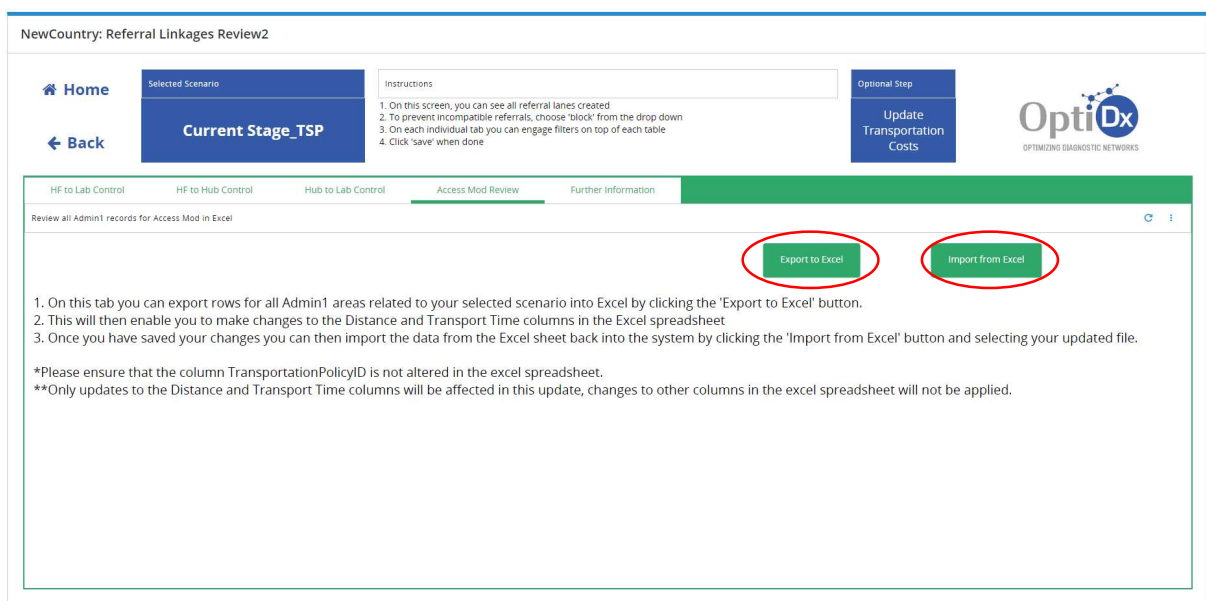
The next step is to order the road-distances and travel times calculated by AccessMod in the exact order than the one in the OptiDx table obtained by email. Therefore, a new table (which is a copy of the emailed table) must be created with only the road-distances and travel times changed. An example of both tables, with the columns that must be changed is displayed in Figure 5 and Figure 6.

The units used to measure travel times differ between AccessMod (minutes) and OptiDx (hours). **AccessMod returns a travel time in minute that must be converted to hours**. Finally, every travel time must be followed by a space and the mention "HR", to replicate OptiDx format. This can be done using a data management software (in our case, we used R (R Core Team, 2017)).

Figure 5 : An example of a referral table exported from OptiDx. Every column must remain unchanged except the two columns highlighted in red ("TransportTime" and "Distance").

Figure 6 : An example of the resulting referral table that can be exported from AccessMod after a referral analysis. The columns in red contain the values that must replace the distances and travel time values in the OptiDx exported table.

8. **Data importation in OptiDx:**

After that, the newly created table can be imported using the "Import to Excel" functionality in the "AccessMod Review" tab of OptiDx.

The "Update referral cost" button must then be pressed. Updated results accounting for travel times and distances from AccessMod can now be obtained and compared between the baseline (straight-line distances) and the scenario (AccessMod distances).

If the process took place during the creation of a new country, then the rest of the creation process can then go on.

9. **Key considerations and common errors:**

a) Key considerations:

1) When road distances and travel times have been imported, the referral linkages should not be modified anymore. If they have been modified (i.e., if a new referral linkage has been created) the modified/created referrals distances and travel times will be calculated using straight-line distances and travel times.
   Several functionalities can modify the referrals in OptiDx and after having imported the road distances, the user should be careful not to:

   - Add new test types
   - Add new locations
   - Add new devices
   - Add modes
   - Overwriting referral linkages

   If the user had used any of these functions, the road distances will have to be recalculated using the new sources and destinations and imported again in OptiDx.

2) If road-distances and travel times are imported in OptiDx during the creation of a country, the subsequent scenarios that will be created will be based on the road-distances and travel times as well, if the referral linkages are not modified.

3) The user should keep in mind that when travel times and travel distances calculated using AccessMod are used, the mode speed that is inputted in OptiDx is overridden. In that case, mode speed corresponds to the travel scenario used in the AccessMod analysis.

4) The user must be sure that all sources can reach all destinations on the road shapefiles (i.e., a fully connected road network). These requirements are similar to the requirements for the use of the Network Analyst in ArcGIS. A few recommendations to verify the connectivity of the network can be found in Annex 3.

5) The user should ensure that the names of the sources and destinations in the shapefile match the names of the sources and destinations used in the table exported from OptiDx and received by email.

b) Common errors:

1) When replacing travel times from AccessMod into the OptiDx template, it is a common mistake to forget converting the travel times calculated by AccessMod from minutes to hours.

2) When replacing travel times from AccessMod into the OptiDx template, it is a common mistake to change the format of the travel times values. This format must strictly follow this format: "X HR" (with only one space).

10. <u>Bibliography:</u>

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Annexes:

1. **Annex 1: Walkthrough of the referral linkages creation step when creating a new country:**

A. When creating a new country, the referral creation step can be accessed by clicking on this button:
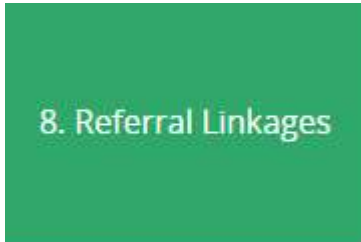
B. The following windows appears and the user must choose between building the referrals from choices or via the historical operation and press "Ok". For this tutorial, I have built the referrals from choices.
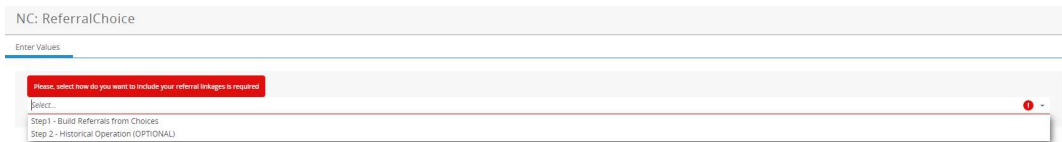
C. After that, the referral type for every Test Type must be specified this can be done by clicking on the corresponding cell next to each Test Type, or by using the "bulk update" functionality (by clicking on ⋮) to modify several cells at once. After that, the user can press "Commit Referral Type". In my case, every test type used a "Direct to lab" referral type.

NC: Referral Type Review

Selected Country

TutoSOP

Instructions

1. Specify how your Test Type is referred in column Referral Type
a) Direct to Lab :Test type must be sent direct to lab
b) Via Hub: Test type cannot be sent direct to lab and must be referred through a Hub
c) Both: Test type can be sent via hub or direct to lab
2) All Test types will be considered on this process

OptiDx
OPTIMIZING DIAGNOSTIC NETWORKS

Test Types	Further instructions

Test Type Information

Test Type	Referral Type
HIV_EID	DIRECT TO LAB
HIV_VL	DIRECT TO LAB
TB	DIRECT TO LAB

Commit Referral Type

D. In the next step, the user can choose how the samples are transported between the source and destination type by admin1 areas as well as the modes to assign to each origin and destination pair. After that, the user can press "Commit Modes to Admin 1).
In my case, I used an "Intra_Admin1 (and across all admin2)" approach.

New Country: Admin1 Selections

E. The next step consists in specifying how test samples can be moved in the admin1 and mode selection that was previously done. More especially, the user can enable or disable the referrals that should not be kept. The user can then press "Commit Modes and Test Types".

F. The final step is to choose how samples can be moved between the admin2 areas (within a same admin1). Similarly, the user can choose which referrals to enable and which to disable.
The user can then press "Build policies based on choices". After that, the referrals will be created.

2. **Annex 2: Recommendations to limit the number of rows in the referral table.**

Two main recommendations can be followed to reduce the number of rows:

A. When creating the referral linkages from choices, the user should remove rows that are very unlikely to be useful because of the distances between the administrative areas. More especially, if a source and a destination are in two administrative areas that are geographically very distant, it is very unlikely that the optimization would favor a referral between these two and therefore can be removed.
B. When some modes of transportation are constrained to certain administrative areas, the referrals that use the other modes of transportation should be removed.

3. **Annex 3: Recommendations to verify that the road network is fully connected:**

To ensure that the road network is fully connected (there are no disconnected patches of roads, "islands"), the user can use a plugin called "Disconnected Islands"(Smythe, 2020). This plugin allows to highlight the disconnected patches ("islands") of roads as well as the main network, hence allowing to repair the network by reconnecting these patches.

4. **Annex 4: Walkthrough in the Workcenter approach version:**

Two paths can be taken:

A. In case the road distance importation occurs at the country creation step:
   i. When the country has been created the user should select "3. Referral Linkages".
   ii. Then, the user should select "ADVANCED USER AccessMod Travel Time and Distances".
   iii. After that, the user can start the exportation by clicking on "Export to Excel"
   iv. The process is then similar to the Version 2.
   v. Finally, importation can start by clicking on "Import from Excel".
      Note: In the Workcenter approach version, the update of the transportation cost is done automatically.

B. In case the road distance importation occurs at a scenario creation step:
   i. When the scenario has been created, the user should select "MANDATORY 5. Referral Lanes".
   ii. Then, the user should select "ADVANCED USER AccessMod Travel Time and Distances".
   iii. After that, the user can start the exportation by clicking on "Export to Excel"
   iv. The process is then similar to the Version 2.
   v. Finally, importation can start by clicking on "Import from Excel".
      Note: In the Workcenter approach version, the update of the transportation cost is done automatically.