Landscape Review of Diagnostic Network and Route Optimization Tools

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Abbreviations

ASLM	The African Society for Laboratory Medicine
CDC	Centers for Disease Control and Prevention
DNO	Diagnostic network optimization
GIS	Geographic Information Systems
LMIC	Low- and middle-income country
RO	Route optimization
SC	Supply Chain
TSP	Travelling salesman problem
VRP	Vehicle routing problem
HF	Health facility

Section 1: Background and Introduction

1.1 Diagnostic Network Optimization

Diagnostics are often unavailable, inaccessible, or too costly in low and middle-income countries (LMICs) (1, 2), where budgets are severely constrained and other competing priorities exist. Ensuring that diagnostics are used optimally is therefore of vital importance in public health planning in such resource-limited settings. The design and planning of diagnostic networks to date have relied mostly on manual methods and expert consensus. This approach is not ideal to analyse complex and multivariate datasets, including demand for services, locations, and capacity, or to explore the current baseline state and future potential scenarios under a range of applied constraints, including costs, allowable service distances, and the turnaround time of results (3).

Diagnostic network optimization (DNO) is a geospatial network analytics approach to plan diagnostic networks consistent with national health goals and strategies, including universal health coverage (4). It helps planners and managers analyse the current diagnostic network and recommend the optimal type, number and location of diagnostics and associated sample referral network that together enable greatest access to services, while maximizing the overall efficiency of the system (4). DNO enables decisions on the best network design in a given setting through evaluation of testing demand, testing capacity and utilization, cost efficiency, access to services, and application of real-life constraints (5, 6).

A DNO exercise is often conducted with the aim of identifying the best-fit approach that helps increase access to diagnostic networks in the most cost-efficient and sustainable manner. DNO is a contextual and adaptable approach, with numerous use cases based on country-specific needs. While the core implementation framework can be universally applied, the process of conducting a DNO is driven by factors unique to each setting, such as the overall purpose, objectives, scope, timing, and the skills and experience of key staff (3, 4). A 2021 guide by FIND describes the key steps involved in the DNO process (3). Table 1 below outlines these steps.

Table 1: Typical steps involved in a DNO process

1. Define scope of work	2. Collect data	3. Build baseline and validate	4. Analyse scenarios and select	5. Implement changes	6. Monitor impact
Identify priorities and set objectives	Collect routine programmatic and survey data in multiple formats	Validate baseline model and document validation criteria	Compare key metrics including access, cost, and efficiency across scenarios for multiple future state network configurations	Assess feasibility of preferred options for implementation	Knowledge transfer
Undertake high-level scenario setting		Check assumptions and outputs with country experts	Evaluate diagnostic capacity utilization, this includes comparing future state cost, capacity and service metrics with baseline and other scenarios	Develop implementation roadmap	Undertake post-optimization benefit audit

1. Define scope of work	2. Collect data	3. Build baseline and validate	4. Analyse scenarios and select	5. Implement changes	6. Monitor impact
			Validate findings with country experts		
Develop detailed project plan and timelines			Develop detailed maps for technology and network referral flows	Implement changes e.g. relocation of existing diagnostics, investment in new technologies, optimization of sample referral flows	Establish impact indicators and monitoring system and conduct regular review

Several Geographic Information Systems (GIS), Route Optimization (RO) and DNO tools are available in the marketplace to support efficient DNO analyses. These tools are explored further in this report.

1.2 Route Optimization

RO is a common activity that often follows DNO work. While RO has predominantly been used in the supply chain industry, it can be applied to a wide range of different situations. RO can be defined as the process of finding the most cost-effective route for a set of stops. RO is more complex than simply finding the shortest distance or fastest time between point A and point B. Key aspects often considered under RO include:

- Minimizing drive time/distance for multiple stops, considering all relevant factors, like number and location of all required stops on the route, vehicle capacities, driver schedules, and time windows for deliveries.

- Defining a set route for all vehicles within the fleet that considers underlying travel conditions and the start and end depots available. In the context of this landscape review, the depots could be laboratories that conduct diagnostic testing. RO is expected to output a route with a start depot, sequence of orders and the end depot. Assumptions for start/end time, service time and vehicle capacity should ideally be considered. The use of hubs and their location(s) is also key.

- Deciding the most efficient routing, i.e. choosing between direct routing or multi-stop routes.

1.3 Geospatial Analysis

Geospatial analysis is a generic term describing several technologies or methods of computational analysis using the earth as a living laboratory (7). The results of geospatial analysis will always change if the location or extent of the geographical frame changes (3, 7). In the context of DNO work, geospatial analytics may include equity, health service geographic coverage, service access and other considerations. Thus, DNO and RO can be viewed as particular forms of geospatial analysis that include an optimization element. However, geospatial analysis can be much broader (beyond laboratories, mapping focus etc.) and does not always include optimization, which aims to provide a solution based on multiple inputs and constraints.

1.4 DNO Tools

Several DNO tools available on the market have been used in public health to support diagnostic network optimization work (5, 8-13). To date, most diagnostic networks have been planned with a focus on laboratory services, and not the whole diagnostic cascade (14, 15). Recently, several groups have applied principles from logistics and supply chain modelling to DNO for use in public health settings (1, 2, 16). In this review, the terms tool and software are used interchangeably.

1.5 Project Objectives

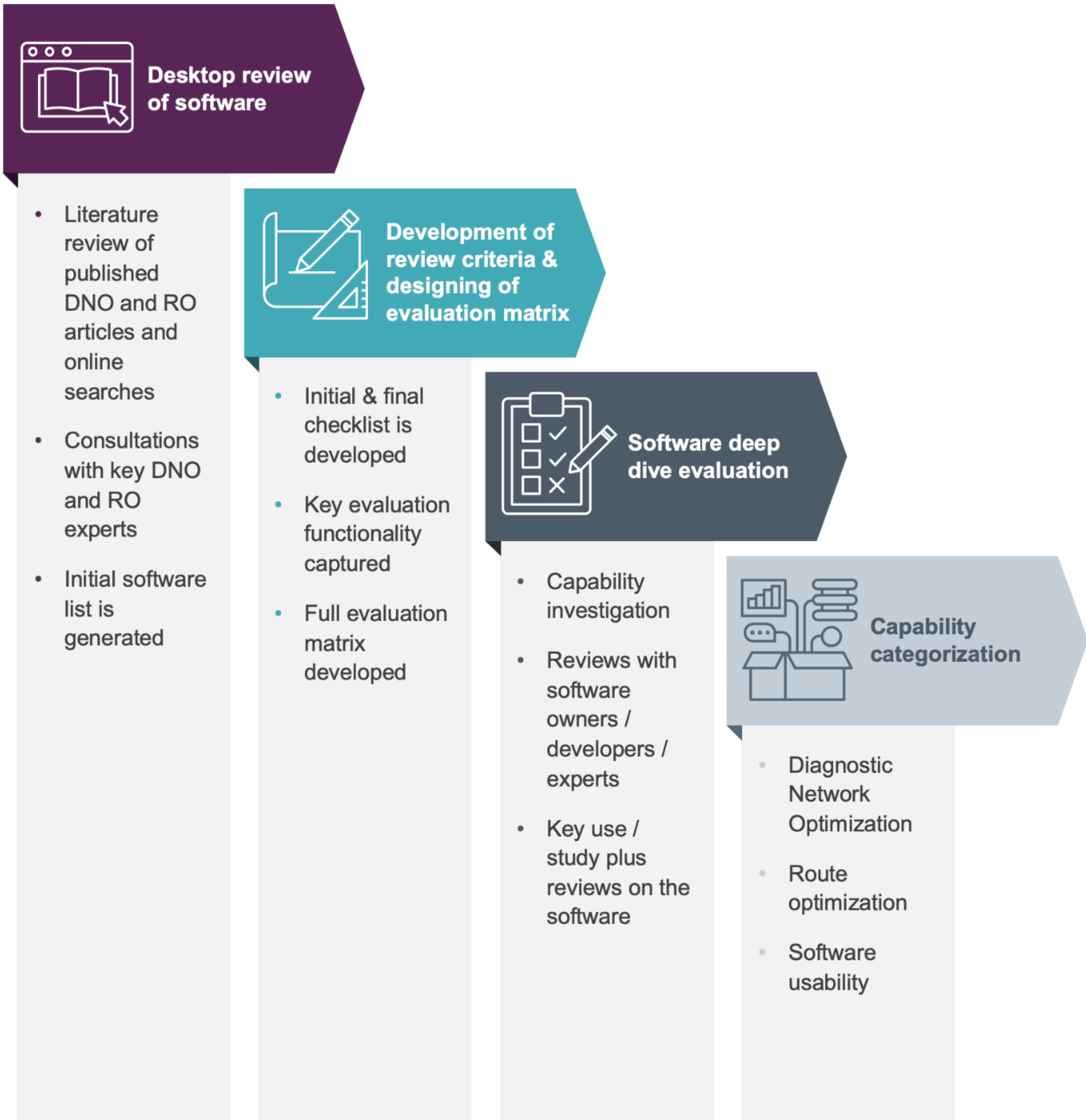
This project set out to conduct a landscape review of DNO and RO tools. This was achieved through the following steps:

1. Determination of what tools are available in the market in order to select tools that qualify for further review.
2. Development of criteria to assess qualified tools
3. Evaluation of selected tools based on developed criteria.

Section 2: Methodology

The identification and evaluation of DNO and RO tools was done using a four-stage process comprising (a) a desktop review, (b) development of review criteria and evaluation matrix; (c) software deep dive evaluation, and (d) capability categorization (Figure 1). The four stages align with the project objectives.

Figure 1: Software identification, criteria development, and tool evaluation stage



DNO, diagnostic network optimization, RO, route optimization.

The following sections explain the steps summarized in Figure 1 in further detail.

Step 1: Conduct desktop review of software as applied and utilized in literature and the market, to select software that qualifies for inclusion in further reviews

An initial list of DNO and RO tools used in the market was identified and compiled based on two main sources:

a) literature review of published DNO and RO articles and online searches; and

b) consultations with key DNO and RO experts.

The literature review and online search and selection was conducted between June and July 2021. Searches were done in Google Scholar and Google using the following search words: *DNO, Route optimization, vehicle routing; diagnostic network optimization, diagnostic network in public health; or route optimization in public health*. The online searches focused on tools used in DNO and RO applications, especially those pertaining to public health. Some of these tools have been utilized in research studies and the results are published in peer reviewed journals (8, 17). As there are numerous tools purely focusing on RO for fleet management and route planning operations (i.e. travelling salesman tools), care was taken to focus on tools that offer functionalities that go beyond standard RO operations and instead focus on routing in public health. This was done by running/viewing demos and/or trial versions of targeted tools.

Exclusion criteria: To pre-qualify the identified tools, each tool was assessed by two reviewers (SN and VB). Tools were excluded if they were: (a) deemed unable to run optimization or (b) software whose suppliers/vendors could not be contacted, or if further information could not be found after diligent searches. A third reviewer (TC) was consulted to resolve possible conflicts and upon discussion, a consensus on inclusion or exclusion was made.

A second round of reviews was then conducted on all prequalified tools by reviewers SN, VB, and TC. Any tool deemed to be non-relevant was subsequently excluded. The results from this second review formed the final qualified list of tools.

Step 2: Development of review criteria

A multi-criteria evaluation matrix was developed based on a three-pronged process:

- First, a review of literature was done to identify key criteria relevant for evaluating DNO and RO tools. Works such as by Nichols et al. 2021 (1), FIND 2016 (4), World Health Organization 2020 (5), and FIND 2021 (3) were key in the development of these initial criteria.

- Second, technical input on the draft criteria was requested from key DNO/RO experts, including from the FIND team. This led to further refinement of initial criteria/questions.

- Third, the developed criteria/questions were reviewed further, based on inputs from key tool experts during arranged deep dive sessions. Virtual calls were held with tool development team members and/or super users of qualified tools.

Step 3: Conduct deep dive sessions and validations for each tool with key experts

Based on the evaluation criteria/questions developed in step 2, a deep dive session was arranged for each qualified tool with key users/developers. The deep dive was done as a two-part process:

I. First, initial interviews were held with development team members and/or super users where questions were asked as per evaluation criteria.

II. A follow-up session was held to further review responses provided and validate the captured comments.

For each criteria/question developed, it was decided that responses would be captured predominantly as follows:

- **Yes:** When the tool is able to address the criteria/question.
- **No:** When the tool is not able to answer the criteria/question.
- **Partial:** When the tool was partially able to address the criteria/question.
- **Comments**: Additional comments were captured and documented where necessary.

Step 4: Evaluate qualified tools based on developed criteria

Tools that were qualified from step 1 were evaluated based on developed criteria within three broad category areas (DNO, RO and software usability).

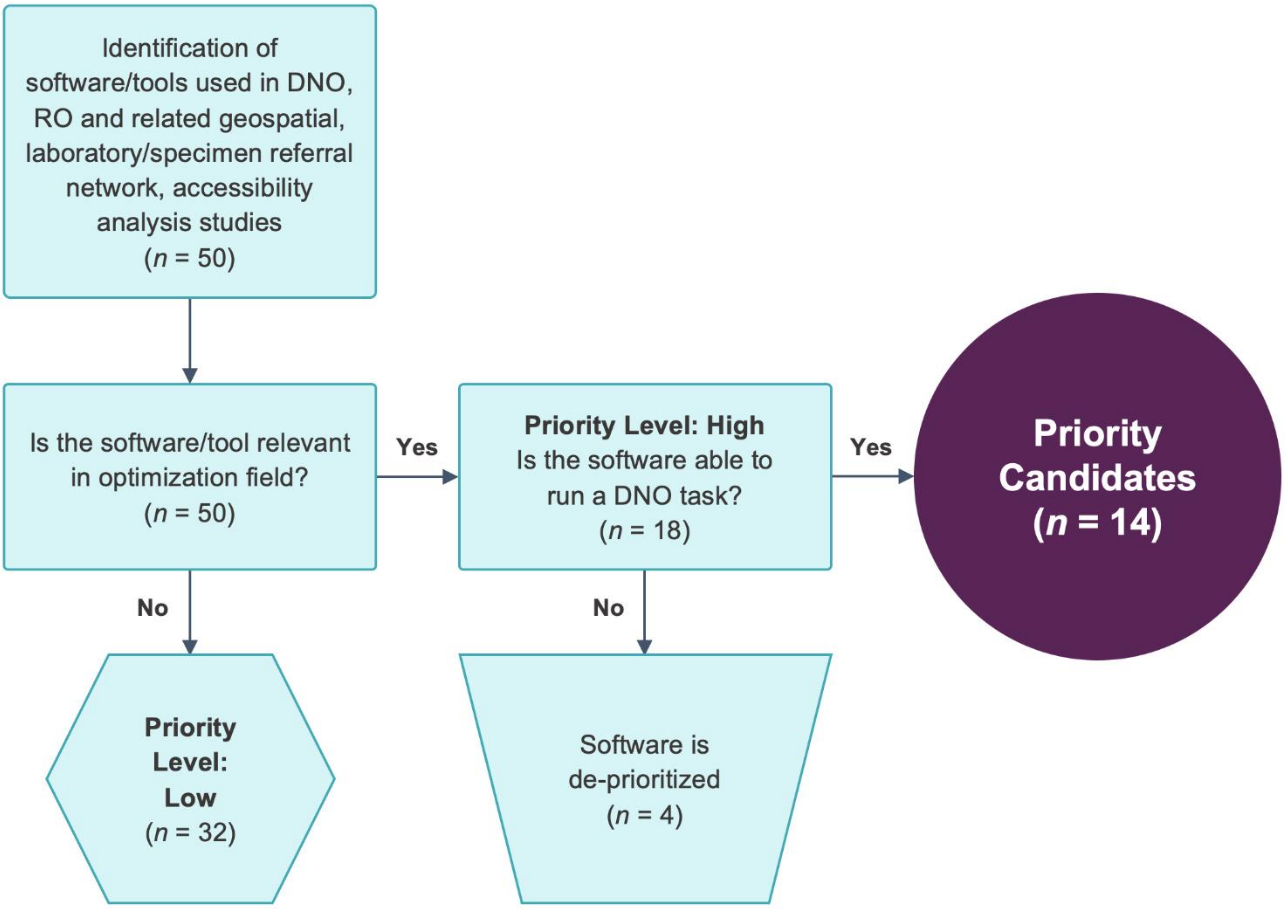
Section 3: Results

The results of the study are presented in three parts that align with steps defined in section 1.5.

3.1 Determine what tools are available in the market in order to select tools that qualify for further review

From the literature review of published articles and online searches and the consultations with key DNO and RO experts, 50 tools were identified and compiled (see Appendix A for the full list). Of the 50 tools, 20 were recommended by key experts in the field of DNO and RO. All 50 tools were then assessed, based on the exclusion criteria. A total of 32 tools did not meet the defined relevance criteria (i.e. failed to prequalify) and hence were dropped. Of the 18 tools that prequalified, a further four were dropped after further reviews under round 2. Thus, 14 tools (listed in table 2) qualified as candidates for further evaluation. Figure 2 below summarizes how the qualified tools were selected from the initial list.

Figure 2: Depiction illustrating how qualified tools (n=14) were derived from the initial list



DNO, diagnostic network optimization, RO, route optimization.

Table 2 lists the qualified tools and their developer/owner details.

Table 2: List of selected (qualified) tools/software

Tool/software name	Developer(s)/owner(s)	Developer/owner website
AccessMod	World Health Organization (WHO)	www.accessmod.org
Advanced Interactive Multidimensional Modelling System (AIMMS)	AIMMS B.V.	https://scnavigator-manual.aimms.com
AnyLogistix	The AnyLogic Company	www.anylogistix.com
Anylogic	The AnyLogic Company	www.anylogistix.com
ArcGIS	Environmental Systems Research Institute (ESRI)	www.esri.com
CDC Diagnostic Network Assessment Tool	Centers for Disease Control and Prevention	www.cdc.gov
Gurobi Optimizer	Gurobi Optimization	www.gurobi.com
LabEQIP	USAID, CDC, LLamasoft	
LabMap	African Society for Laboratory Medicine (ASLM)	www.aslm.org
OptiDx	FIND, LLamasoft (a Coupa company). USAID's Procurement and Supply Management (PSM) Program	https://www.optidx.org/
Prime Thought (RouteXL & SpatialXL)	PrimeThought Software Solutions	https://primethought.biz/
QGIS	QGIS Development Team	www.qgis.org
QGIS – STATA / R / Microsoft Excel	QGIS, StataCorp, The R Project, Microsoft	www.qgis.org/ , www.stata.com, www.r-project.org
Supply Chain Guru	LLamasoft (a Coupa company)	https://globalllamasoftwebsite.azurewebsites.net/supply-chain-guru/

3.2 Develop criteria to assess qualified tools

Figure 3: Definition of broad evaluation categories used

Category	Description related to criteria/questions
Diagnostic network optimization	• Covers full DNO elements that are specific to network optimization. Objectives such as minimizing costs, maximizing access, minimizing turnaround time and transport, DNO device placement within given constraints and other specifics that did not fall within other categories. This includes DNO functions such as specimen referral networks, scenario modelling, service distance and time constraints and GIS analysis.
Route optimization	• Covers the specific process of route optimization, where a set of orders and labs are optimized. This includes processing and determining the most cost-efficient route, including all factors for that scenario of interest.
Software usability	• Covers the general category that examines certain aspects of a software that relate to software usability, methods of data preparations (e.g. drag and drop versus coding required, ease of use etc.). • Additionally, this is specifically related to the software and the operating costs thereof, including initial set-up costs, ongoing costs (including expenses such as server maintenance fees, network equipment, maintenance fees, annual upgrade costs, technical support staff etc.) and projected costs.

DNO, diagnostic network optimization, GIS, geographic information system.

Table 3 presents the developed criteria for each of the three categories. In total, 32 criteria were proposed for assessing DNO, RO, and software usability.

Of these,18 variables that cover different DNO aspects were proposed. These included scenario analysis capability; referral linkages; service distance and time constraints options; definition of, updates to and removals of health facilities, hubs, laboratories, and devices; multiple disease capability; and five questions related to costs. Five broad criteria were defined for RO and nine different questions around software usability were developed.

Appendix B provides metadata/definitions of developed criteria.

Table 3: Criteria/questions developed under each category

Main Category	Criteria/Question
DNO	**DNO criteria***
	1. Users can run a scenario analysis (If "No", skip to next question)
	2. Users can conduct scenario analysis including advanced setting of parameters
	3. Users can control referral linkage creation and input system frequencies as well as backend coding
	4. Users can control service distance and time constraints at national, sub-national, lane and test level
	5. Users can add or remove health facility/hub/lab to/from the diagnostic network
	6. Users can run geospatial analysis (including RO), export (different data format tables & maps) and import both spatial and non-spatial data
	7. Users can define and update multi-disease testing and input advanced device parameters
	8. Users can define, update and add lab-device placement
	9. Users can create an optimized or historical baseline model
	10. Models in the tool can include a defined time horizon i.e. monthly, bi-monthly, quarterly and annual
	11. Users can define device setup costs (overhead cost, start-up cost, fixed cost, variable cost, human resources cost) including variable cost per test and shifts
	12. Users can define quality assessment score for labs
	13. Users can update and define cost per km, mode speed for multiple modes, and frequency of sample pick-up is defined by location, test type and mode
	DNO questions
	14. Can the tool provide the optimized total cost of the network, including test cost, device cost and transportation cost at national, administrative Level 1, administrative Level 2 and lab level?
	15. Can the tool provide capacity utilization, number of tests done at a combination of national, administrative Level 1, administrative Level 2 and lab and test level?
	16. Can the tool provide samples referred in different distance bands?
	17. Can the tool provide transportation cost outputs at national, administrative Level 1, lane and test level?
	18. Is the tool able to provide detailed route optimized costs, including facility sequences with the functionality of allowing models to select the optimal health facility-hub-lab combinations on multi-stop routes and direct routes based on inputs like demand, distance, frequency?
RO	1. Update functional status of individual labs: users can open/close labs
	2. Users can run an optimization analysis with the following objectives: a) Cost optimization b) Service optimization c) Sequential optimization
	3. Users can define the maximum hours during which a driver is available
	4. Users can run RO using modes available in DNO models for the country and can also run one specific model for a single administrative area or multiple areas
	5. Users can define the average halt time (service time) at health facilities
Software usability	1. Are there initial software setup costs?
	2. Are there ongoing software costs?

	3. This includes expenses such as server maintenance fees, network equipment maintenance fees, annual upgrade costs and technical support staff.
	4. What is the nature of software (proprietary, open Source or open license)?
	5. Does the tool have key use cases and case studies conducted and publicly available?
	6. Does the software tool have public use reviews?
	7. What is the usability of the tool – coding (programming) or drag and drop?
	8. What level of expertise and/or skillset is needed to use the tool?
	9. What is the hosting platform: web, Excel or desktop?

* Criteria metadata is provided in Appendix B

DNO, diagnostic network optimization, RO, route optimization.

3.3 Evaluate selected tools based on developed criteria

The 14 selected tools were evaluated using the developed assessment criteria. Evaluation results are presented in Tables 4–6. Tables 4a and 4b capture evaluations for DNO, while tables 5 and 6 present results for RO and software usability, respectively.

DNO results: DNO evaluations show that six of the 14 selected tools (AnyLogic, Gurobi Optimzer, LabMap, OptiDX, Prime Thought [Route XL and Spatial XL], GGIS -STATA/R/Excel) met all criteria specified under this study.

RO results: results for the RO evaluation show that six tools (Anylogistix, Gurobi Optimizer, LabMap, PrimeThought, Supply Chain Guru, OptiDX) met criteria specified in the study.

Software usability results:
Highlights under software usability show that:

a) Six of 14 evaluated tools were open source while another six were proprietary. While this information could provide initial guidance to user choices (especially those interested in open source solutions), further information that includes strengths and weaknesses of each tool (open source or proprietary) will come in handy to guide users on those choices. Many studies, e.g. Singh et al. (18), delve into details of open source and proprietary software comparisons and provide details on the pros and cons of each option. This study did not, however, include evaluations of the strengths and weaknesses of selected tools.

b) Eight of 14 tools had use cases and case studies publicly available. This appears to suggest that these eight provided readily available information to potential users which could assist them with quicker tool familiarization, learning and understanding of tool capability in general. Given that DNO is a fairly new field, one could argue that the eight tools appear to give users an upper hand with tool usage and exposure compared with tools without use cases.

Table 4a: Diagnostic network optimization evaluation

Software	Users can run a scenario analysis (If "No", skip next question)	Users can conduct scenario analysis including advanced setting of parameters	User can control referral linkage creation and inputting system frequenting as well as backend coding	Users can control service distance and time constraints at national, Admin I, lane and test level	Users can add / remove HF / hub / lab to the diagnostic network	Users can run geospatial analysis (including VRO), export (different data format tables & maps) and import both spatial and non-spatial data	Users can define and update multi-disease testing and input advanced device parameters	User can define, update and add lab device placement	Users can create an optimized or historical baseline
ArcGIS	Yes	Yes	Yes	Yes	Yes	Yes	No	Partially	Partially
AccessMod	No	No	No	Yes	Yes	Partially	Partially	Yes	Partially
AIMMS Bespoke platform	Yes	Yes	Yes	Yes	Yes	Partially	Yes	Yes	Yes
Anylogic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Anylogistix	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
CDC Network Assessment Tools	No	No	Partially	No	Yes	Partially	No	Yes	Yes
Gurobi Optimizer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LabEQIP	Yes	Partially	Partially		Yes	Yes			
LabMap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OptiDx	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prime Thought (RouteXL & SpatialXL)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
QGIS	Partially	Yes	Yes	Yes	Yes	Yes	No	Partially	No
QGIS – STATA / R / Excel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Supply Chain Guru	Yes	Yes	Yes	Yes	Yes	Partially	Yes	Yes	Yes

Note: For cells with no information, we were unable to determine the outcome for that tool, or we could not contact the vendor, or the criteria/question is not applicable.

Key

Yes	Partially	No

HF, health facility, VRO, vehicle route optimization.

Table 4b: Diagnostic network optimization evaluation

Software	Criteria: Models in the tool can define time horizon i.e. monthly, bi-monthly, quarterly and annual	Users can define device set-up costs (overhead cost, start-up cost, HR cost) including variable cost per test & shifts	Users can define EQA score for labs	Users can update and define cost per km, mode speed for multiple modes & frequency of sample pick-up is defined by location, test type & mode	Can the tool provide the optimized total cost of network including test cost, device cost and transportation cost at national, Admin 1, Admin 2 and lab level	Can the tool provide capacity utilization, # of tests done at a combination of national, Admin 1, Admin 2 and lab & test level	Can the tool provide samples referred in different distance bands	Can the tool provide transportation cost outputs at national, Admin 1, lane and test level	The tool is able to provide detailed route optimized costs including facility sequences with the functionality of allowing models to select optimal HF-hub-lab combinations on multi-stop routes and direct routes based on inputs like demand, distance, frequency
ArcGIS	No	Partially	No	Yes	No	No	Yes	Yes	Partially
AccessMod	No	No	No	No	No	Partially	Yes	No	No
AIMMS Bespoke platform	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Partially
Anylogic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Anylogistix	Yes	Yes	Partially	Yes	Yes	Yes	Yes	Yes	Yes
CDC Network Assessment Tools	Yes	No	Partially	No	No	Yes	No	No	No
Gurobi Optimizer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LabEQIP				Yes			Yes	Yes	Partially
LabMap	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OptiDx	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Prime Thought (RouteXL & SpatialXL)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
QGIS	No	Partially	No	Partially	No	Partially	No	No	Partially
QGIS – STATA / R / Excel	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Routific	No	No	No	No	No	No	No	No	No
Supply Chain Guru	Yes	Yes	Partially	Yes	Yes	Yes	Yes	Yes	Yes

Note: For cells with no information, we were unable to determine the outcome for that tool, or we could not contact the vendor, or the criteria/question is not applicable.

Key

Yes	Partially	No

EQA, external quality assessment; HF, health facility; HR, human resources.

Table 5: Route optimization evaluation

Software	Criteria: Update functional status of individual labs: users can open / close labs	User can run multiple optimization analyses with the following objectives: a) Cost optimization b) Service optimization c) Sequential optimization	Users can define the max hours during which driver is available	Users can run VRO using modes available in DNO models for the country and can also run once specific model for single admin area or multiple	Users can define the average halt time at HFs
ArcGIS	Yes	Yes	Yes	Partially	Yes
AccessMod	Yes	Partially	No	No	No
AIMMS Bespoke platform	Yes	Yes	Yes	Partially	Yes
Anylogic	Yes	Yes	Yes	Partially	Yes
Anylogistix	Yes	Yes	Yes	Yes	Yes
CDC Network Assessment Tools	Yes	No	No	No	No
Gurobi Optimizer	Yes	Yes	Yes	Yes	Yes
LabEQIP		Partially	Partially		Yes
LabMap	Yes	Yes	Yes	Yes	Yes
OptiDx	Yes	Yes	Yes	Yes	Yes
Prime Thought (RouteXL & SpatialXL)	Yes	Yes	Yes	Yes	Yes
QGIS	Yes	Yes	Partially	Yes	Partially
QGIS – STATA / R / Excel	Yes	Yes	Partially	Yes	Partially
Supply Chain Guru	Yes	Yes	Yes	Yes	Yes

Note: For cells with no information, we were unable to determine the outcome for that tool, or we could not contact the vendor, or the criteria/question is not applicable.

Key

Yes	Partially	No

DNO, diagnostic network optimization; HF, health facility, VRO, vehicle route optimization.

Table 6: Software usability evaluation

Software	Initial setup costs	Ongoing costs (including expenses such as server maintenance fees, network equipment maintenance fees, annual upgrade costs, technical support staff	Nature of software	Tool has key use cases and cases studies conducted & publicly available	Tool public use reviews	Usability – Coding (programming) vs drag and drop
ArcGIS	Proprietary	Yes	Proprietary	Partially	Yes	Both
AccessMod	Open source	Open source	Open source	Yes	Yes	Drag & drop
AIMMS Bespoke platform	Proprietary	Proprietary	Proprietary	Yes	Yes	Both
Anylogic	Proprietary	Proprietary	Proprietary	Yes	Yes	Both
Anylogistix	Proprietary	Proprietary	Proprietary	Yes	Yes	Drag & drop
CDC Network Assessment Tools	Open source	Open source	Open source	No	No	Drag & drop
Gurobi Optimizer	Proprietary	Proprietary	Not an off-the-shelf software but an optimization service	Not an off-the-shelf software but an optimization service	Not an off-the-shelf software but an optimization service	Both
LabEQIP	Open source	Open source	Open source	Yes	No	Both
LabMap	Open source	Open source	Open source	Yes	No	Both
OptiDx	Open access	Open access	Open access	Yes	No	Drag & drop
Prime Thought (RouteXL & SpatialXL)	Proprietary	Proprietary	Proprietary	No	Yes	Both
QGIS	Open source	Open source	Open source	Partially	Yes	Both
QGIS – STATA / R / Excel	Open source	Open source	Open source	Partially	Yes	Both
Supply Chain Guru	Proprietary	Proprietary	Proprietary	Yes	Yes	Both

Table 6: Software usability evaluation

Software	Criteria: Level of expertise and/or skillset needed to use the tool	Criteria: Hosting platform: Web, Excel or Desktop	Criteria: Are there any manuals/user guides available?
ArcGIS	Advanced *(Advanced GIS skills & data management)*	Web & Desktop	Yes *(Available at www.esri.com)*
AccessMod	Medium	Desktop	Yes *(Manual available on AccessMod website)*
AIMMS Bespoke platform	Advanced *(Modelling: or specialist; end use: SC planner)*	Web	Yes
Anylogic	Advanced *(Expert skills to develop but easy to use)*	Cloud & Standalone	Yes
Anylogistix	Easy to use *(Easy to develop and easy to use)*	Desktop	Yes
CDC Network Assessment Tools	Easy to use *(Basic MS Excel skill required)*	Excel	Yes
Gurobi Optimizer	Advanced	Not an off-the-shelf software but an optimization service	Not an off-the-shelf software but an optimization service
LabEQIP	Medium *(Basic GIS & data management skills)*	Desktop	*Yes* *(www.ghdonline.org/uploads/GLI_Guide_specimens_web_ready_94qcDur.pdf, https://www.ghsupplychain.org/resource/labeqip*
LabMap	Medium to Advanced *(Basic GIS & data management skills)*	Desktop	*Yes*
OptiDx	Medium to Advanced	Web	*Yes*
Prime Thought (RouteXL & SpatialXL)	Easy to use *(Basic Excel skill required)*	Excel	*Yes* *(available on website)*
QGIS	Advanced *(Advanced GIS & data management skills)*	Desktop	*Yes*
QGIS – STATA / R / Excel	Advanced *(Most functions are labour intensive)*	Desktop	*Yes*
Supply Chain Guru	Advanced	Desktop	No *(No publicly available manuals – Only obtainable with the license agreement. Additionally, there are paid e-learning provided)*

GIS, geographic information system.

Section 4: Conclusions

DNO exercises aim to review and/or redesign diagnostic network set-up to increase access, reduce costs and/or improve device utilization. DNO is a fairly new field, which is developing with advancements in technology DNO work as known today appears to have gained traction after 2010. Previously, DNO tasks, like modelling, mapping laboratory networks and sample transport networks, were mainly undertaken using a supply chain and geospatial/GIS perspective, with tools built for those sectors. However, today, there are an increasing number of tools available to support DNO and RO analyses. Choosing the right tool is particularly important to support structured DNO and RO analyses.

This DNO and RO landscape review set out to determine DNO and RO tools available in the market and develop criteria to assess the tools. This landscape assessment was done with the broader purpose of providing initial guidance for users who plan to make DNO tool choices based on current tools available in the market. While the review does not cover detailed assessment of each selected tool, it provides a foundation for further work in this area. To our knowledge, this is one of the first studies to attempt such an assessment in the DNO and RO area.

Based on the study findings, we recommend considering the following general guidelines when selecting tools for DNO/RO:

- Deciding on which DNO and/or RO tool to choose for an assignment is not an easy or straightforward endeavor. Several factors may need to be considered, including the tasks would-be users seek in a tool, as well as assessing the technical capability of potential tools to address such tasks. This study has developed a general methodology for identifying, criteria for assessing and an approach for evaluating DNO and RO tools. Users who want to evaluate DNO tools now have an initial framework to replicate or adapt.

- It is worth noting that many DNO projects are different, as a result of different country settings, the situational context, and/or underlying skills of end users or test types. Thus, different tools may be applicable to different DNO scenarios. It should also be noted that DNO analysis is not a one-time activity but needs updates and iterations. Hence, countries deciding upon a suitable tool should consider, amongst other things, their current needs and plans to build in-country capacity to conduct analyses.

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