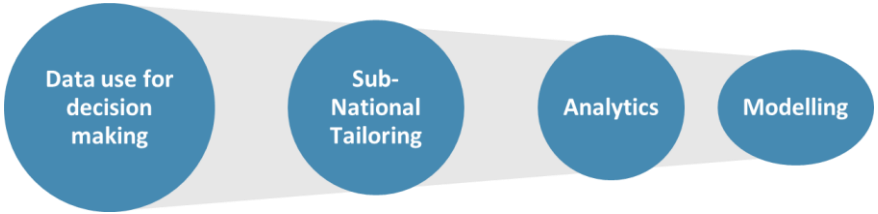
The use of modelling in the process of subnational tailoring of malaria interventions and strategies

July 18, 2024

SNT as part of a broader initiative of data-use for evidence-based decision making



Data use for evidence-based decision making

Utilizing data to generate evidence and inform malaria-related decisions—such as policy, strategy, and planning—at the local level is key for effective malaria interventions.

Subnational tailoring of malaria interventions (SNT):

The use of local data and contextual information to determine the appropriate mixes of interventions and strategies, for a given area, for optimum impact on transmission and burden of disease

Analytics for SNT

Epidemiological analyses for SNT were presented last week. **Modelling** analyses complements these analyses and should not be considered in isolation.

Introduction to modelling

https://pxhere.com/en/photo/56906

Role of models

- **Visualization and communication**: Models provide a simplified representation of complex systems, facilitating understanding and communication.

- **Scenario analysis**: Models allow for the evaluation of different scenarios and hypotheses, aiding in the decision-making process.

- **Optimization and resource allocation**: Models help identify the most efficient and effective ways to allocate resources.

- **Impact evaluation**: Models are used to assess and manage risks (e.g. safety of a building or effectiveness of interventions)

- **Planning**: Models assist in anticipating and preparing for future needs

They help us to think rationally and can support decision making

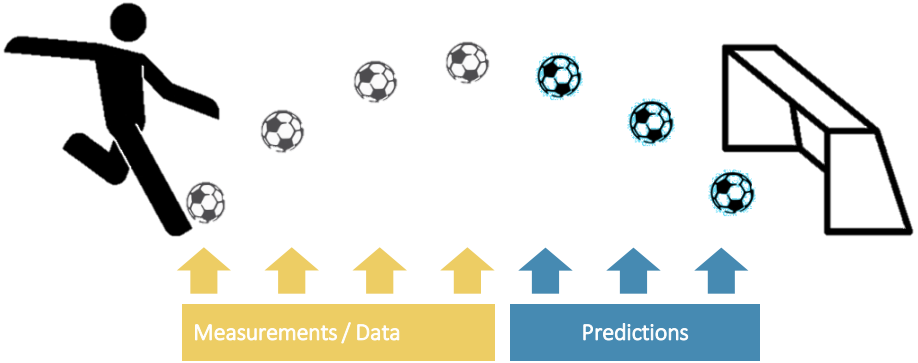
“All models are wrong, some are useful“

Attributed to George Box

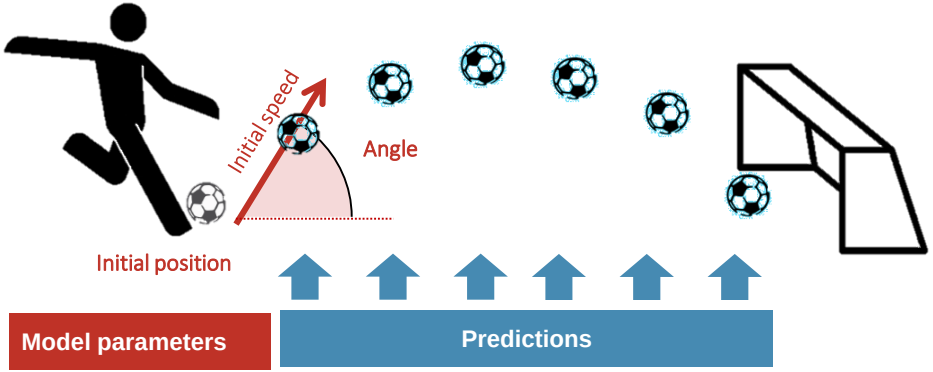
They never represent the exact reality

Understand two different types of models

Statistical models



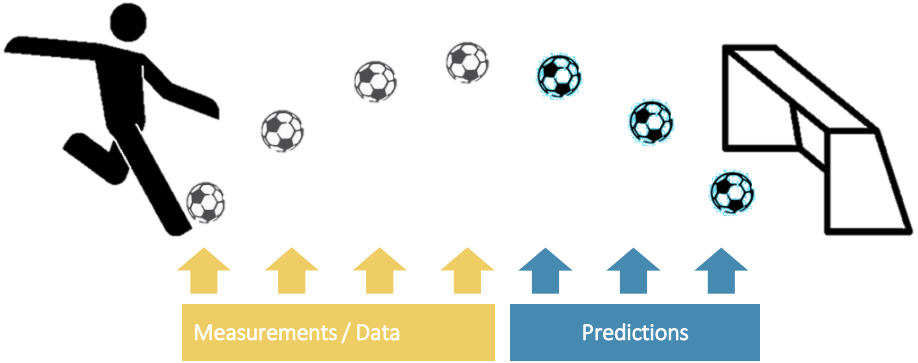
Mathematical models

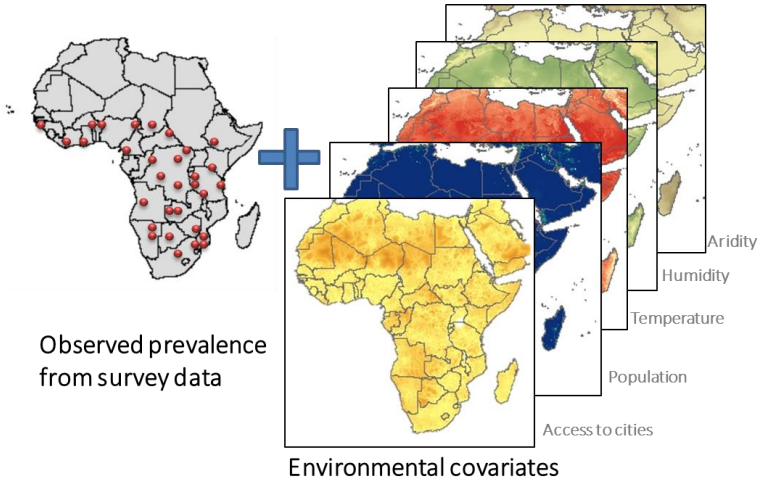


Requirements	**Observed data**	**Understanding of the mechanism that drives the system**
Example of useful applications	Malaria risk mapping	**Malaria transmission models (=dynamical models)**

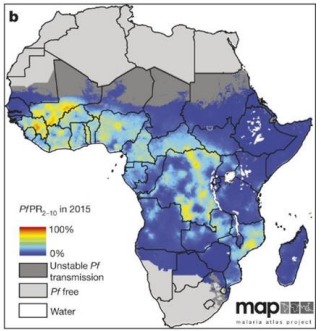
How does this apply to malaria ?

Statistical models





Today, we will not talk about statistical models

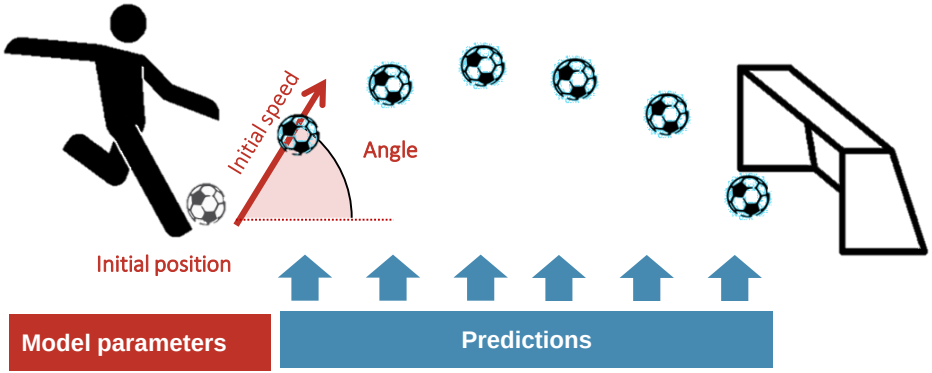


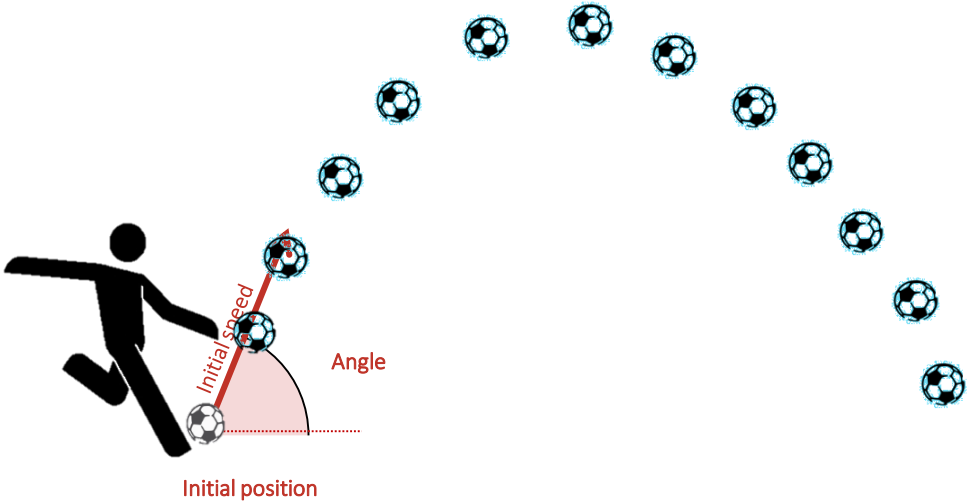
Bhatt, S et al. "The effect of malaria control on Plasmodium falciparum in Africa between 2000 and 2015" Nature vol. 526,7572 (2015): 207-211.

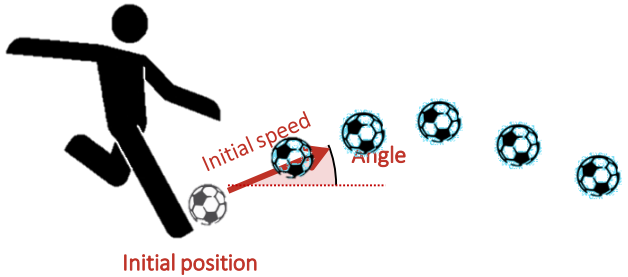
Understand the value of dynamical models

With the mathematical model, we can explore various scenarios, i.e.
what would happen if we …

Mathematical models







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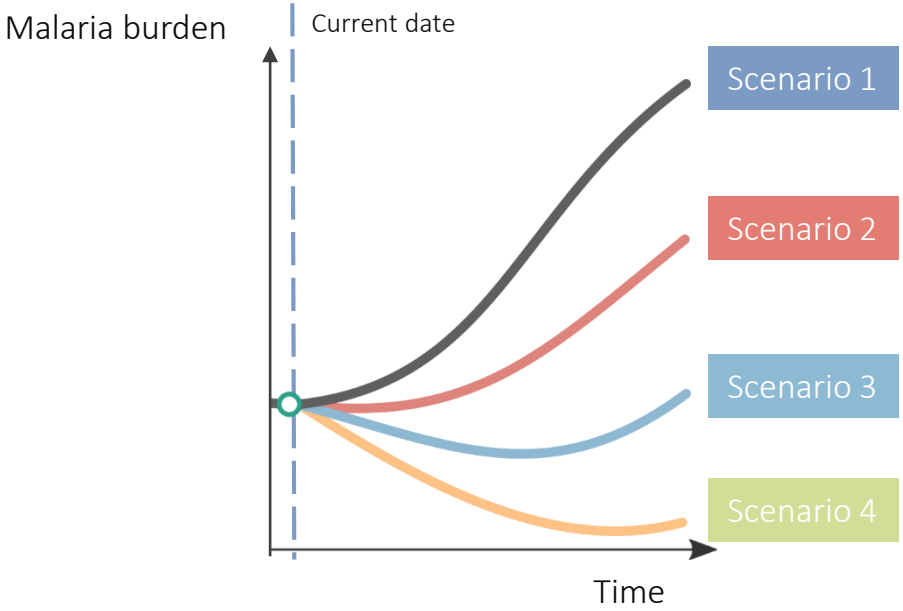
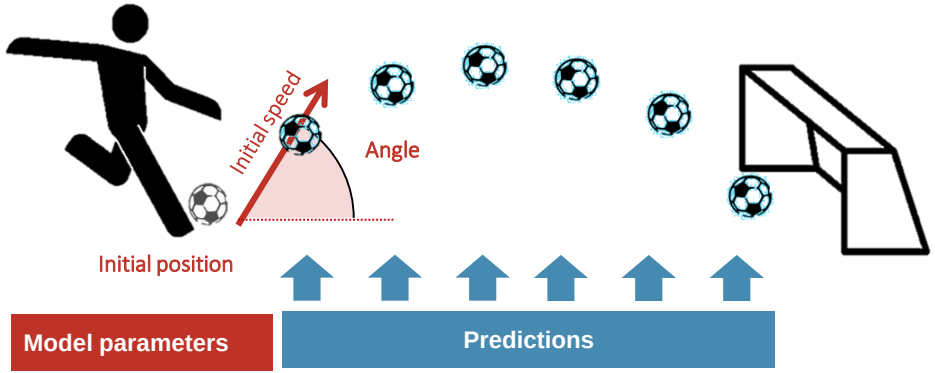
How does this apply to malaria ?

With the mathematical model, we can explore counterfactual scenarios, i.e.
what would happen if …



Mathematical models



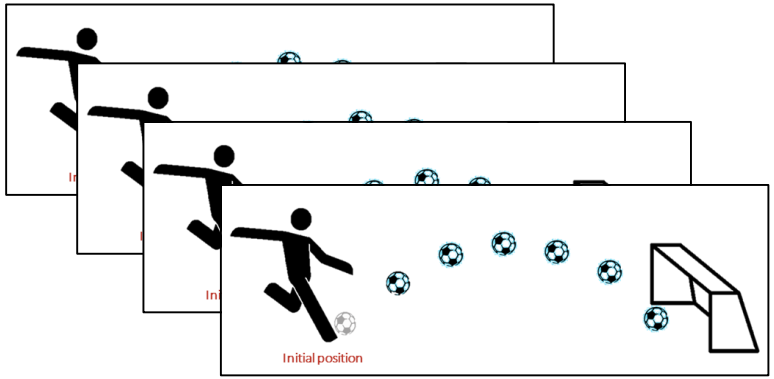
Scenarios can be almost anything including different interventions, different coverages, different frequency of distribution, different targeted age-groups…

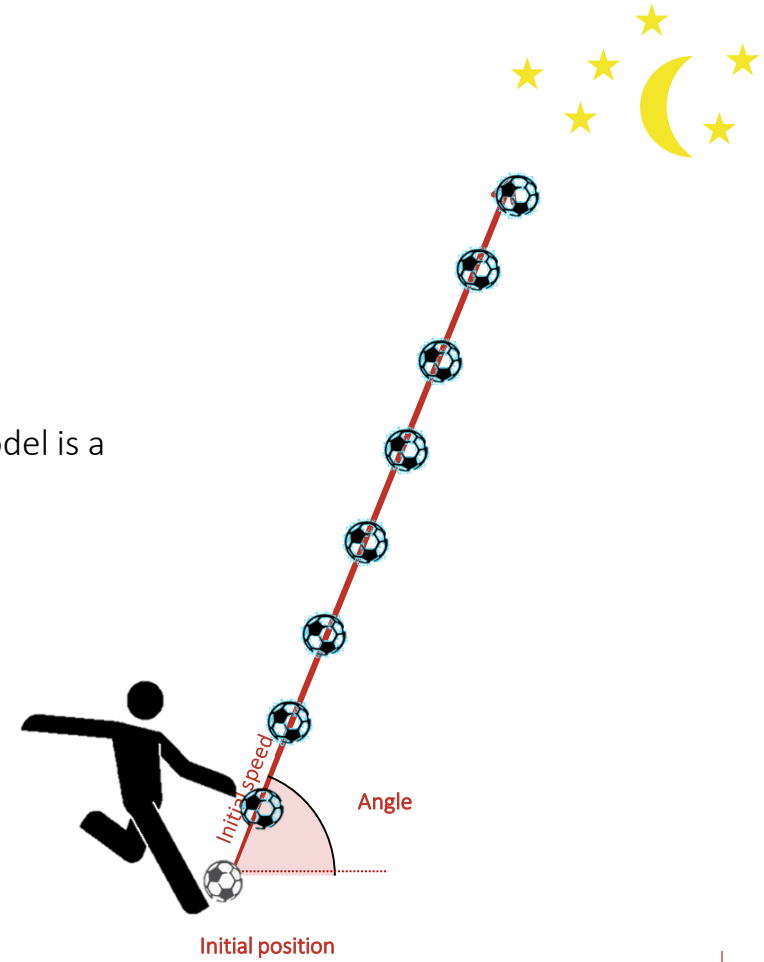
How does this apply to malaria ?

With the mathematical model, we can explore counterfactual scenarios, i.e.
what would happen if …

Even unrealistic scenarios !

This is why it is important to have data, to make sure the model is a correct representation of reality

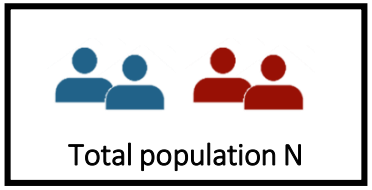


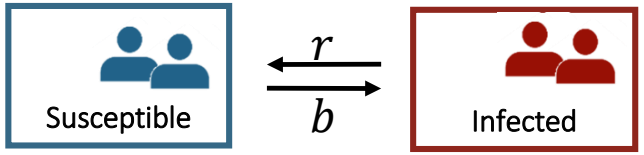


How to model

Building a simple model: the SIS model

Each sub-population is assumed to have the same history of malaria infection and interventions





New people getting infected

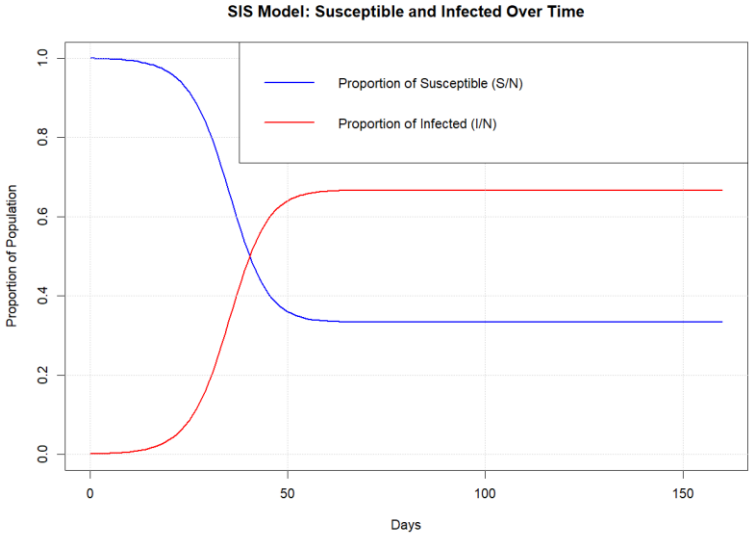
Variation in the number of infected $= b * \frac{I * S}{N} - r * I$

Recovering people

b : $transmission\ rate$

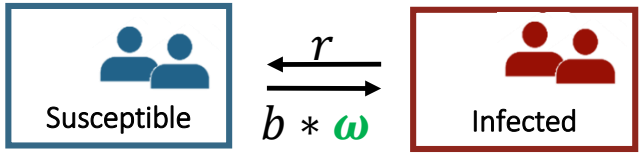
N: $Population\ size$

r: $recovery\ rate$



Building a simple model: the SIS model with an intervention

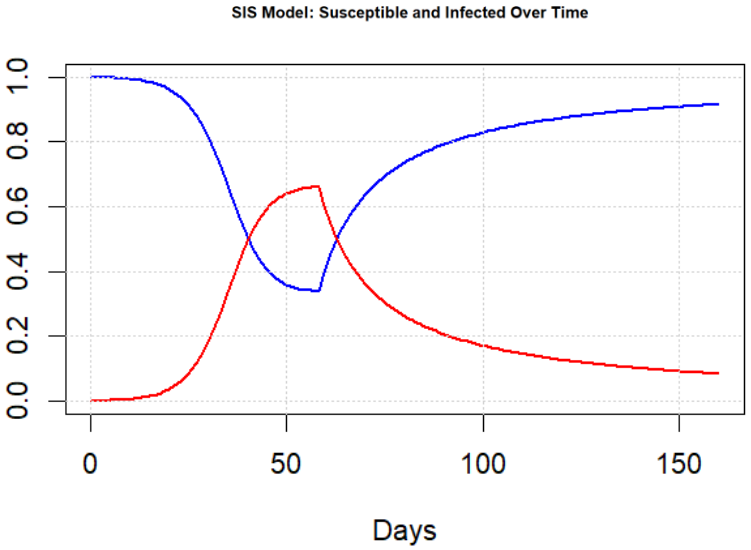
Each sub-population is assumed to have the same history of malaria infection and interventions



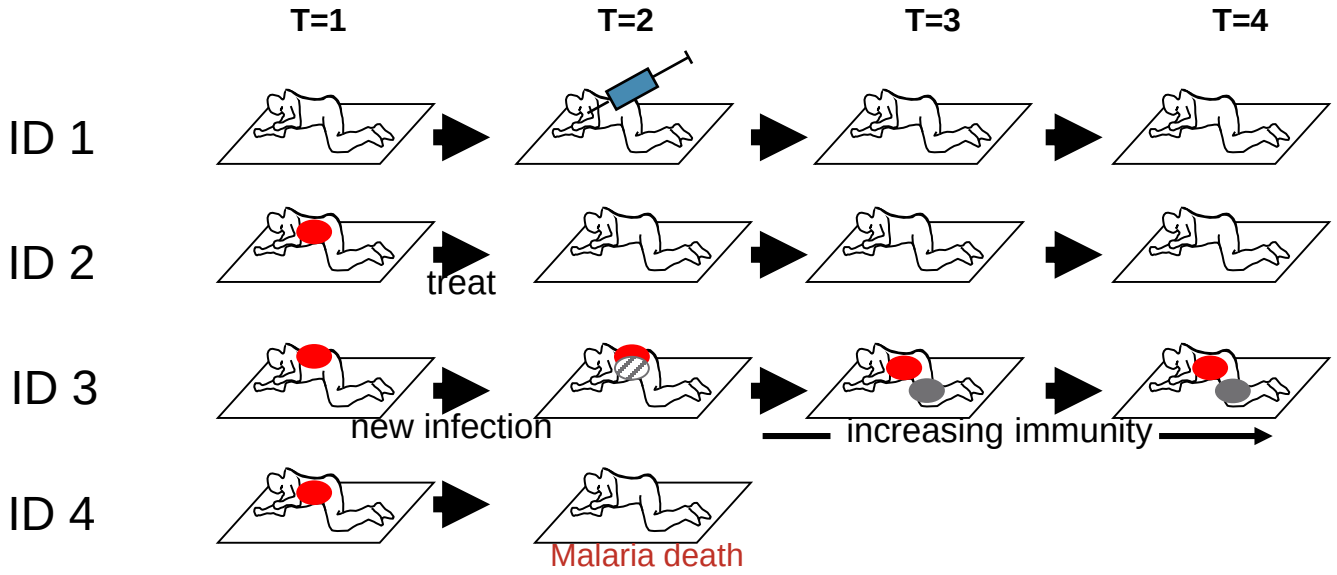
Variation in the number of infected

$$= b * \omega * \frac{I * S}{N} - r * I$$

b : $transmission\ rate$
N: $Population\ size$
r: $recovery\ rate$
ω: $effect\ of\ intervention$



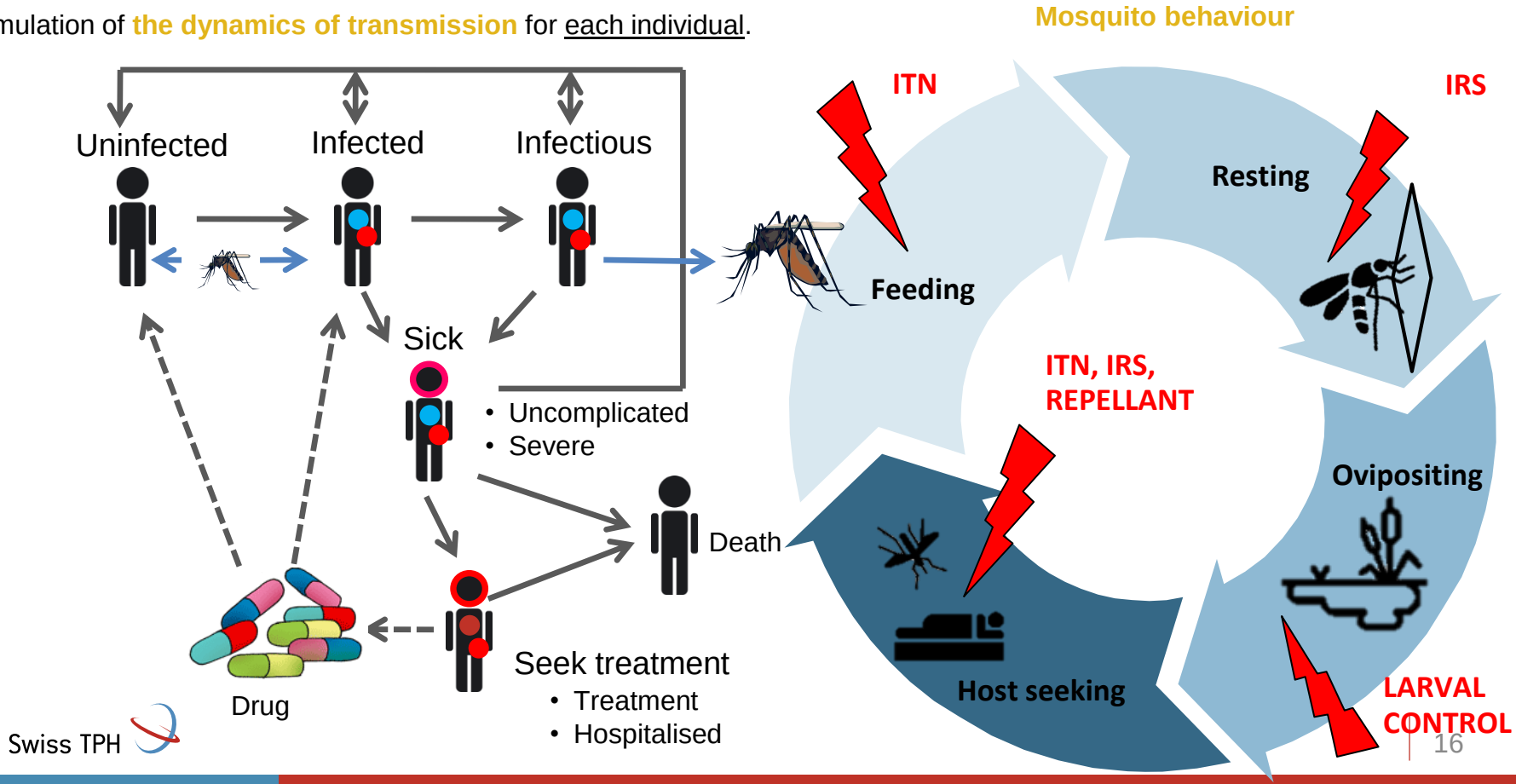
Building a more complex model: an individual based model



Each individual has a different history of malaria infection and interventions

Example of OpenMalaria : an individual-based model for malaria

Simulation of **the dynamics of transmission** for <u>each individual</u>.



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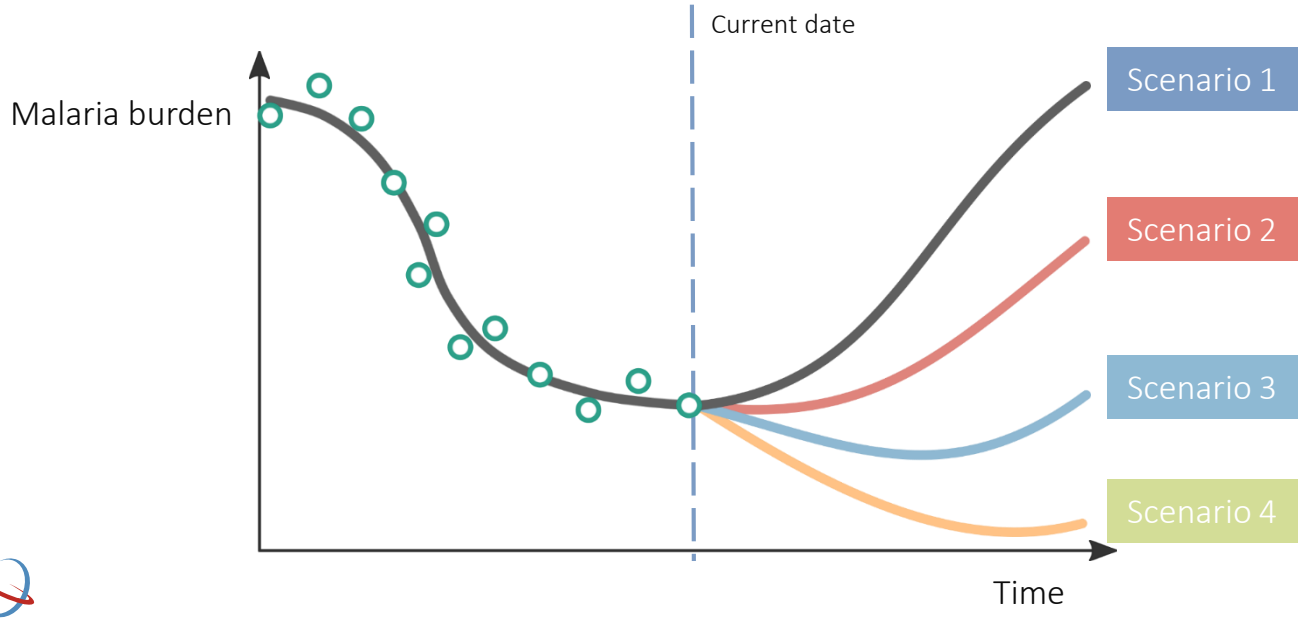
Application of models for country-specific malaria strategies

Reproduce past trends

Simulate future scenarios

Data: Use all available country data to represent past trends of malaria burden

Action: What would happen if we implemented…



Limitations

Data quality	The accuracy of models heavily depends on the quality and quantity of available data.
Uncertainties	Each model has inherent uncertainty that must be considered by decision-makers.
Representation of reality	Models simplify reality and may not reflect dynamic and evolving conditions.
Interpretation of results	Results can be misinterpreted if the assumptions and limitations of the model are not well understood.
Operationalisation	Models assume that interventions will be implemented as planned, which may not always be the case in practice.

Modelling to inform policy and strategies – the SNT process

History of malaria model to inform policy

1916

•"[…] from such reasoning alone we derive the very important practical conclusion that in order to counteract malaria anywhere we need not to bannish *Anopheles* there entirely – we need only to reduce their numbers below a certain figure"

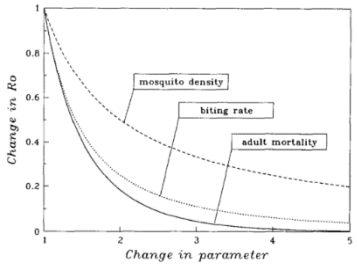
•-Ronald Ross, 1916

Source: National Library of Medicine

Learning: No need to kill all mosquitoes but only to reduce their density

Start of LSM

1956



Koella et al., 1990

•"This powerful influence of changes in the mortality rate of mosquitoes on the transmission of disease by them is the explanation of the brilliant success of residual insecticides."

•- George McDonald, WHO bulletin, 1955

Source: National Museum of Health and Medicine

Learning: Better increase adult mosquito mortality than reducing their density

Better IRS than LSM

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Today, policy-related questions are more specific and still benefit from epidemiological and modeling analyses to find answers.

Where to prioritize new interventions?

When and how often should we deploy chemopreventions?

What is the true burden of malaria ?

What package of interventions would be most effective to reduce burden or achieve elimination?

When is the most effective time to deploy interventions?

Has malaria been eliminated?

What is the impact of interventions?

Where is the risk of malaria?

What is driving transmission?

What are the risk factors for malaria transmission in a certain place or population?

Should chemopreventions strategy be extended demographically or geographically?

What is the impact of removing an intervention and where should we prioritize the removal?

Who should receive an intervention?

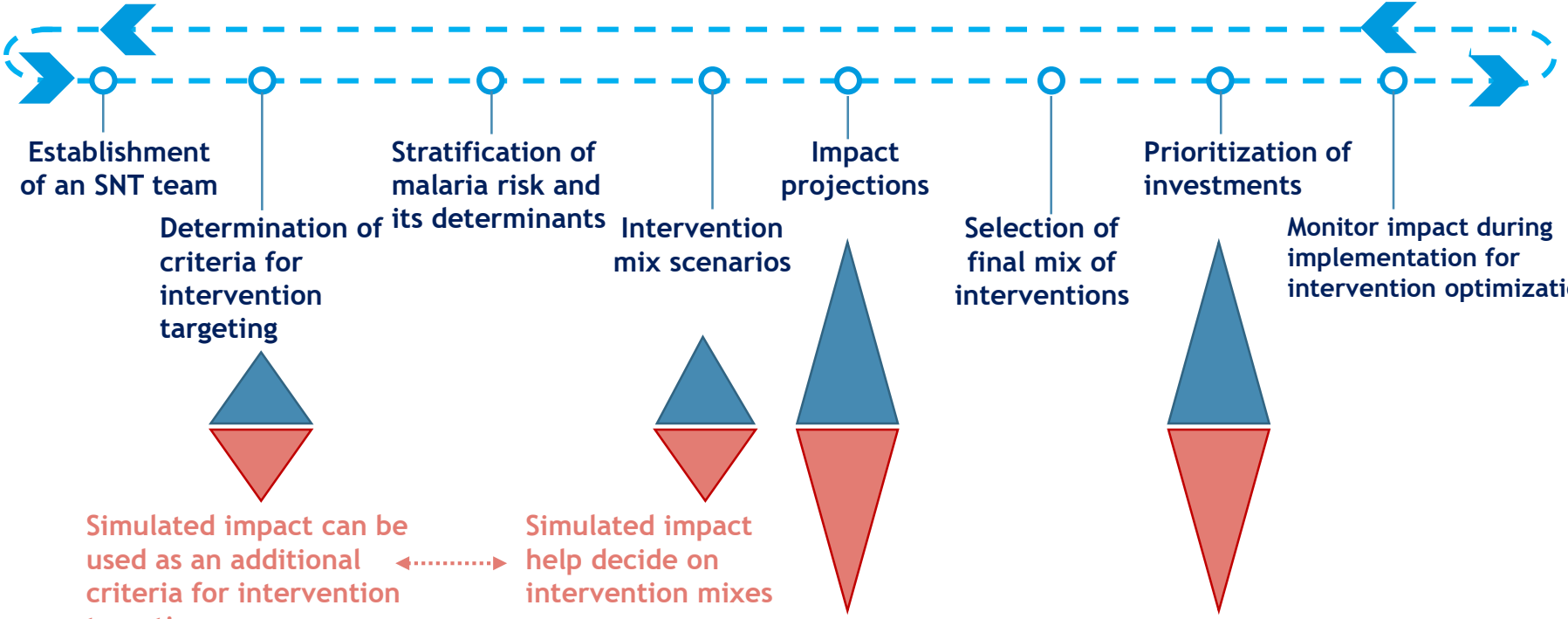
Can elimination be achieved by a certain date?

What is the retrospective impact of implemented interventions?

Where do patients seek treatment?

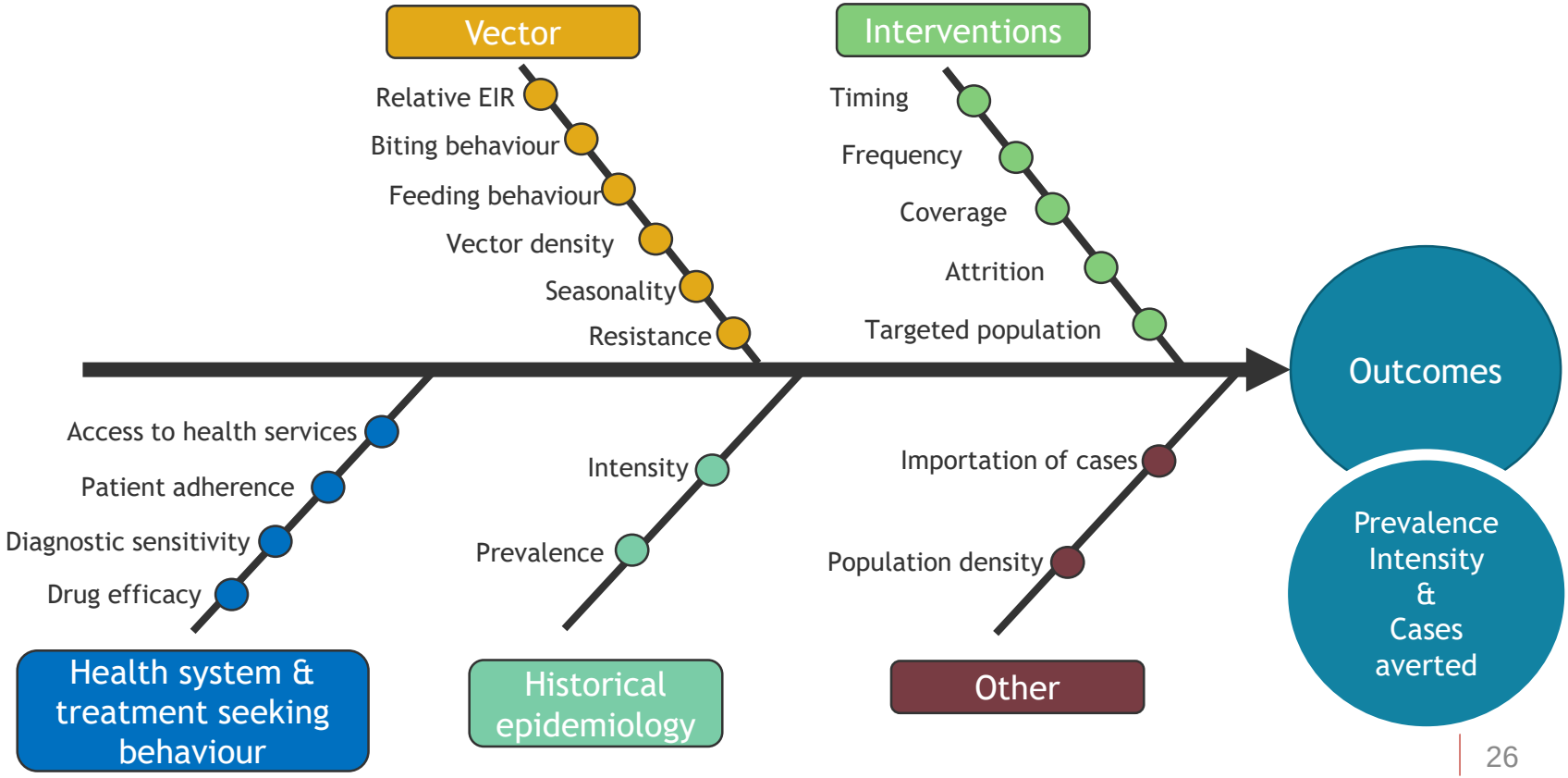
Decisions need to be made…
… with none, incomplete or evolving evidence…

The SNT process and the role of modelling



**Adapted from WHO slide*

Representing subnational areas requires extensive information.



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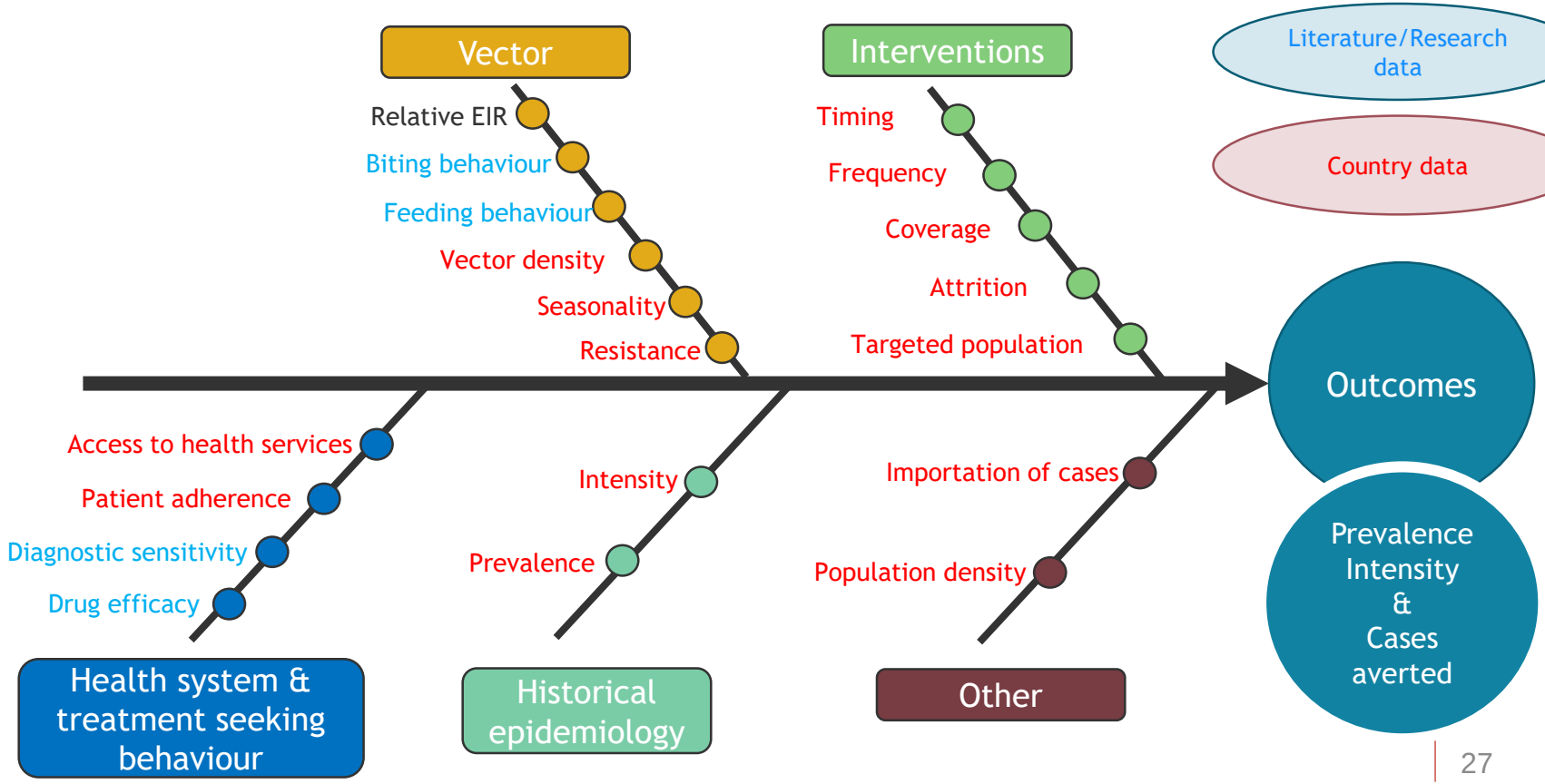
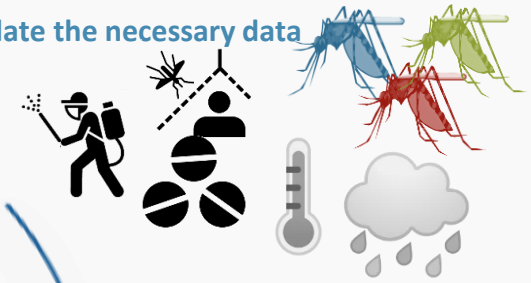
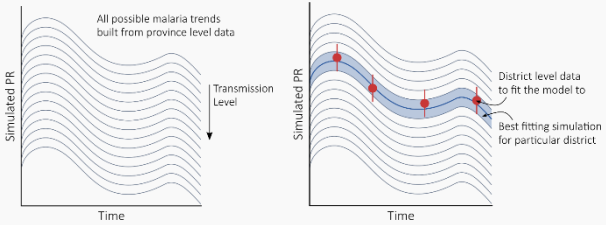


1. Understand the question and choose the appropriate model

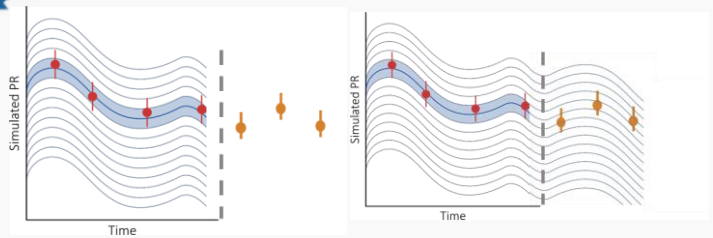
2. Collate the necessary data



3. Calibrate the model



4. Validate the model



5. Use the model to answer the question

6. Discuss the results

Iterate !

In summary

Start with an objective and relevant question

Ensure access to relevant data

Engage, Collaborate & Communicate with NMCPs & local partners

The process is as important as the outputs

Iterate, iterate, iterate

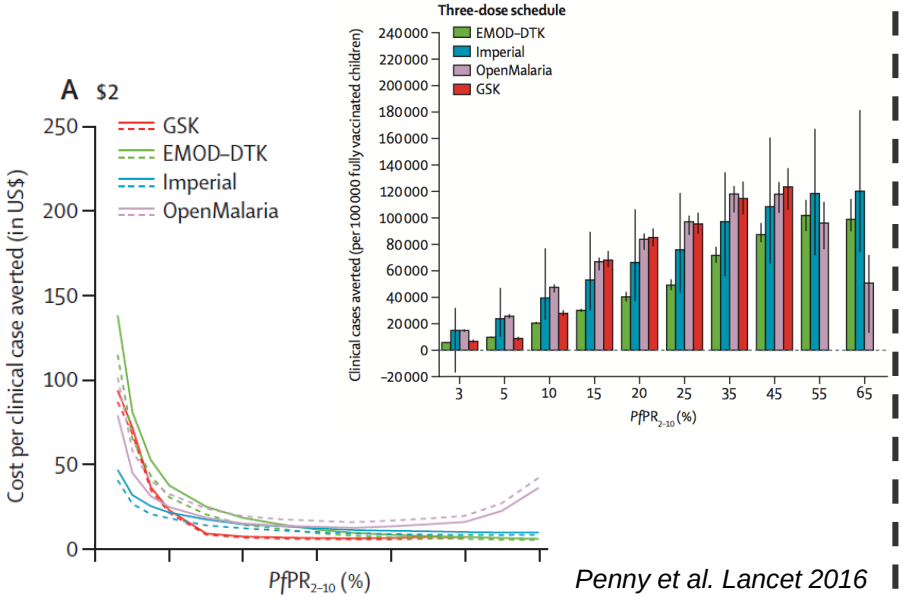
Have actionable results

Examples of use of modelling for strategic planning and SNT

Traditionally, modelling had been used to inform global policies

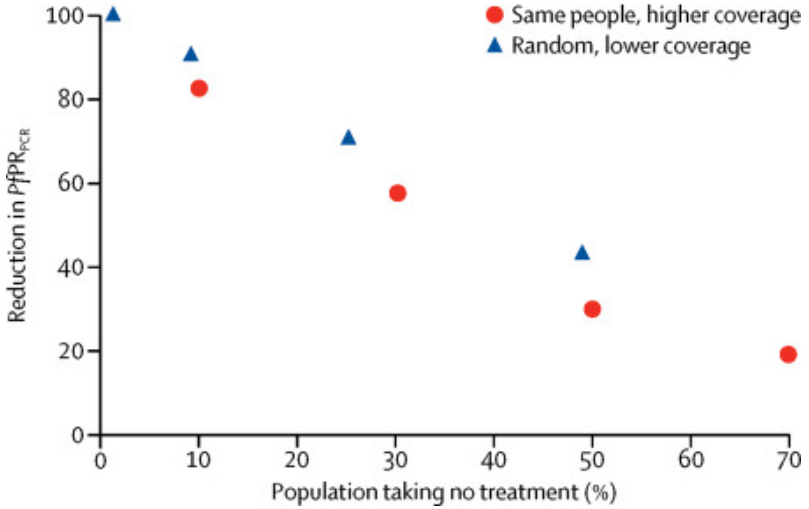
Question: For intervention X, what should be the recommendations for deployment?

What is the impact of the RTS,S vaccine?
Because efficacy is not very high, is this vaccine worth its cost? What would happen in other settings and larger populations beyond the trial?



Penny et al. Lancet 2016

What would be the impact for MDA deployment?
Should drugs be delivered to same individuals or randomly? At what transmission intensity would it be the most impactful? Is the impact larger if extended to a second year?



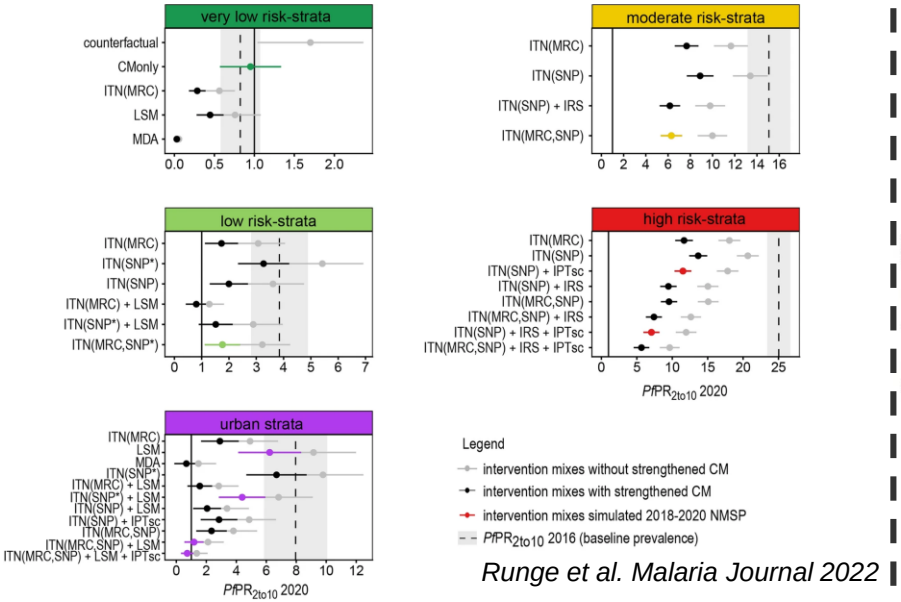
Brady O. et al, *Lancet Global Health* 2017

For the first time in 2018, modelling was used to inform the update of a country National Malaria Strategic Plan - Tanzania

Question: For strata X, what intervention mix should be implemented? And what would be its impact?

Which combination of interventions has the greatest impact within each stratum?

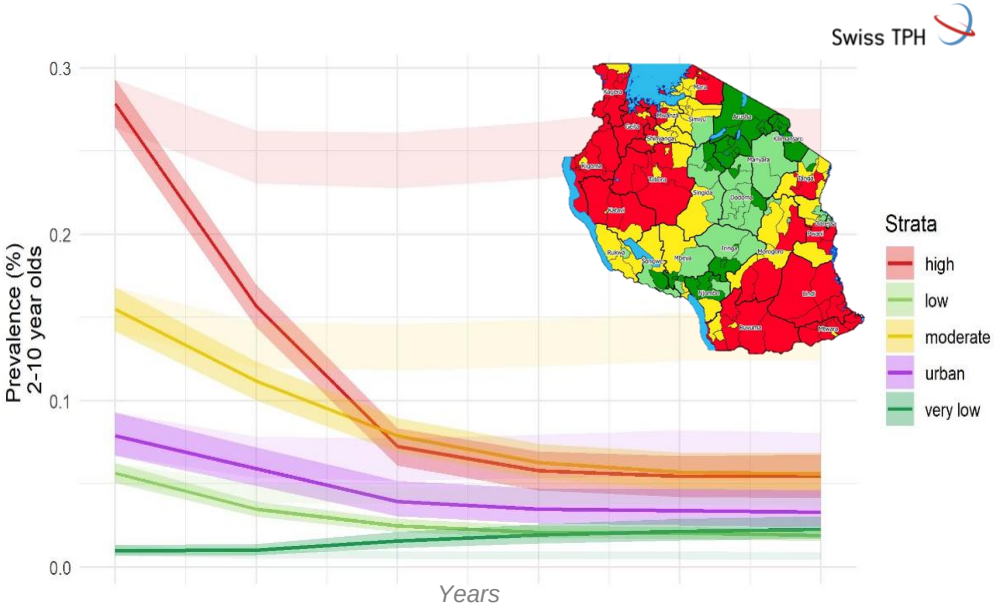
What are the benefits of IPTsc in high and moderate-risk areas? How does the impact differ between various bednet delivery mechanisms?



Runge et al. Malaria Journal 2022

What would be the impact of a future strategy?

What is the expected impact in each strata? How would the impact differ compared to continuing our current approach? What should the revised targets be?

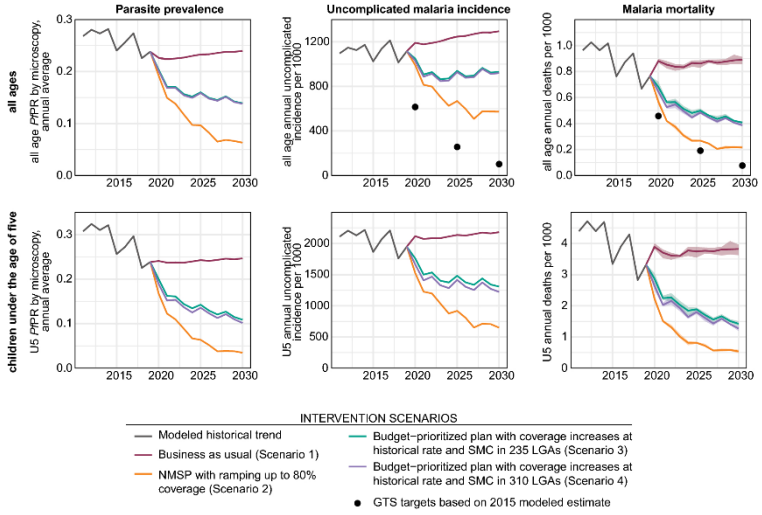


Since the launch of the HBHI initiative, modelling has been widely used to inform more National Strategic Plans

Question: What is the impact of various scenarios identified with the epidemiological analyses?

In Nigeria, what is the national impact of the NMSP for various coverage levels?

Should coverage of LLINs or number of districts covered by SMC be prioritized? How do the projections compared to the GTS targets?



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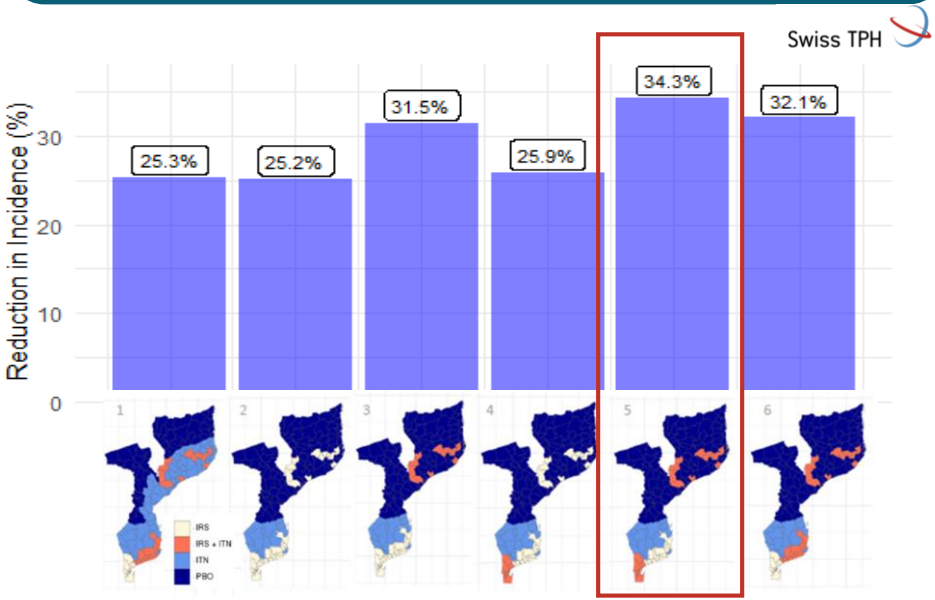
Ozodiegwu et al. Malaria Journal 2022

In Mozambique, what is the nationwide impact of different vector control allocation strategies?

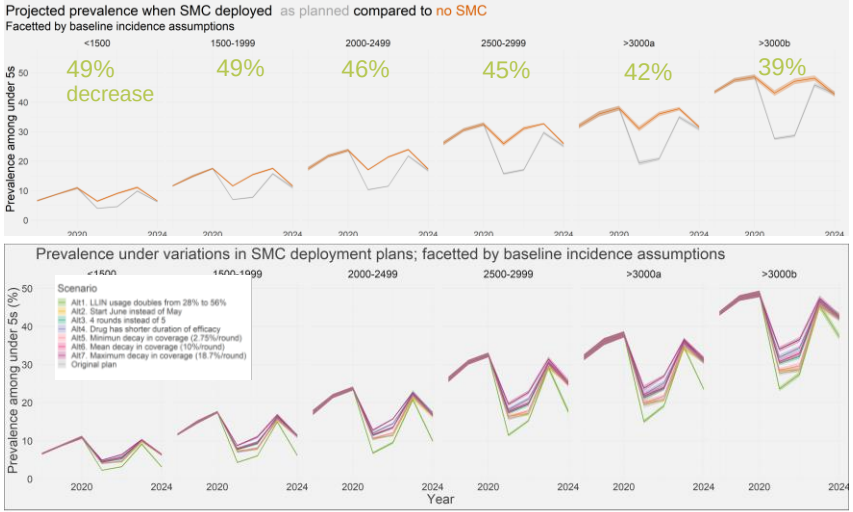
Would the combination of IRS to LLIN result in a significant impact? Should LLIN be discontinued in certain areas? Where should IRS be targeted for maximum effectiveness?



Modeling was also used to enhance and refine deployment strategies

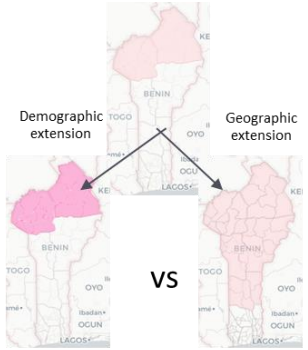
Question: What should be an optimal implementation strategy to result in the maximum impact?

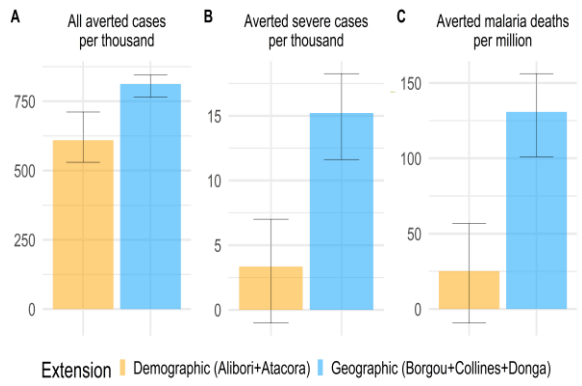
For the implementation of SMC in Karamoja, Uganda, at what level of transmission intensity would it have the most impact? *Where should we pilot SMC to capture the highest impact? What if the anticipated implementation conditions change?*



Owen et al. Nat. medicine 2022

For the extension of SMC in Benin, should it be geographic or demographic? *What is the expected impact if 5-10 years old received SMC where it is already implemented vs if 3 new regions received SMC for 0-5 years old?*





Lemant et al. submitted

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Recently, modelling results have also been considered alongside other important factors such as cost and cost-benefits

Question: What strategy should be implemented? And what would be its impact?

What is the most cost-effective strategy?

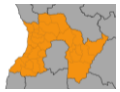
What is the highest impact we can achieve with the funding and commodities available?

7M over budget

USD 20M funding constraint

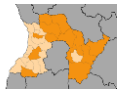
PYR nets

CFP nets



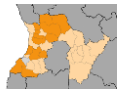
Ideal

100% CFP coverage
Unaffordable



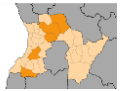
Scenario 1

15 munis with CFP, 50% PYR coverage in provincial capitals



Scenario 2

13 munis with CFP, 2 munis at 56% and 1 munis at 0% PYR coverage



Scenario 3

5 munis with CFP, 1 munis at 36% PYR coverage

*Munis = municipalities

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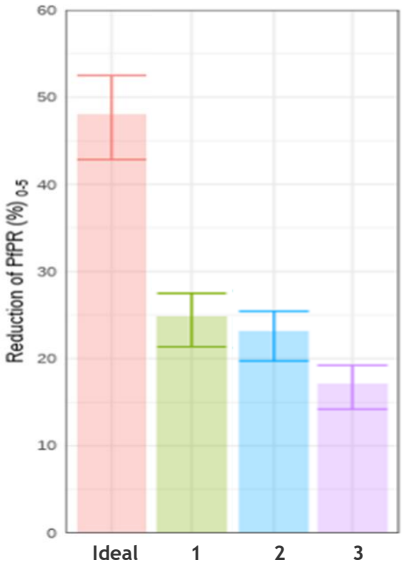

What is the most cost-optimised strategy?

Given a fixed budget, what allocation of combinations of interventions would have the greatest impact on malaria burden?
How does this allocation change for increasing available funding?
How does the optimal strategy compared to the NMSP?

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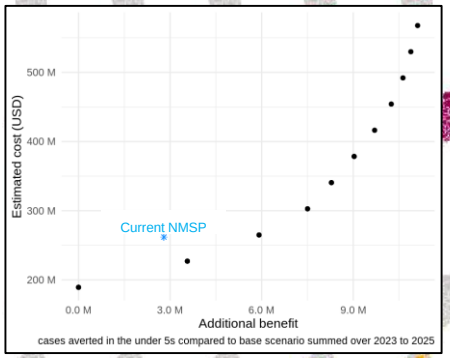
SMC

RTS,S

IRS



Increased budget from base scenario

Analyses used for GC7 and highly praised by TRP

Epidemiological and modelling analyses are essential tools for ensuring that decision making is informed by evidence and has the highest chance of success




Descriptive analysis	Epidemiological and modelling analyses	Decision-making	Monitoring and Evaluation
• Assess data availability and quality. • Graphs, tables and maps can often be sufficient to review and analyse data. • Generate hypotheses for further analysis.	• More complicated questions may require the use of epidemiological and modelling analyses. • External partners can provide support in close collaboration with the program.	• Ensure that data and analytics are incorporated into decision making to provide further sources of evidence and maximise impact.	• **Analytics is not a one-off activity but should be incorporated into regular M&E.** • Outputs can be regularly updated when more data is available and when the context changes over time.

Evidence and data-informed decision making

Swiss TPH

Thank you for your attention

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