Optimising Africa

How to Optimise Investments in the Network of Medical Centres along the African Highways

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Lunteren Conference LNMB & NGB

19 Januari 2011

Erasmus Universiteit Rotterdam

North Star Alliance

ORTEC

Contents

North Star Alliance

- Truck drivers:
  - HIV
  - Infection diseases
  - No access to medical help

- Results:
  - Staff turnover
  - Dispersion of HIV

North Star Alliance

- Solution:
  - Information
  - Testing
  - Prevention
  - Treatment

Problem description

- North Star wants to grow
  - 85% access
  - Dense network
- Challenge:

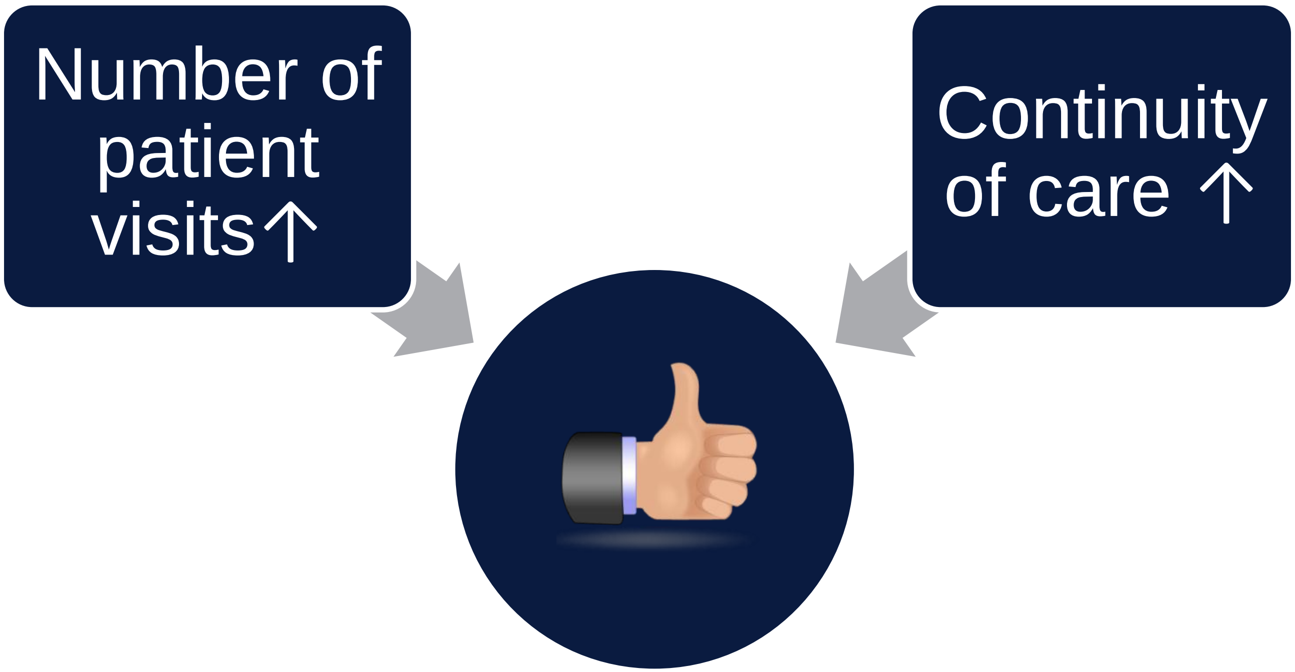
  Opportunistic growth ➔ Strategic growth

Problem description

- Questions:
  - Where to locate new RWCs?
  - How to invest a budget in new RWCs and/ or new employees?

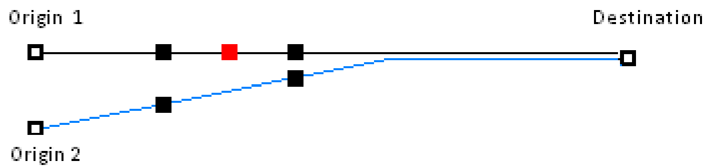
Problem description

- What determines the fitness of an investment?

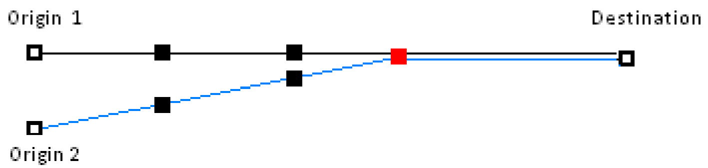


Problem description: continuity of care

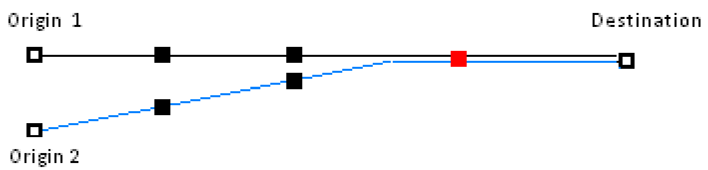
- When does an investment improve continuity of care?
  - Bad



  - Better



  - Best



Problem description: summary

- Questions:
  - Where to locate new RWCs?
  - How to invest a budget in new RWCs and/ or new employees?

- Best answer:
  - Patient visits ↑
  - Continuity of care ↑

Solution

- **Mixed Integer Programming model:**

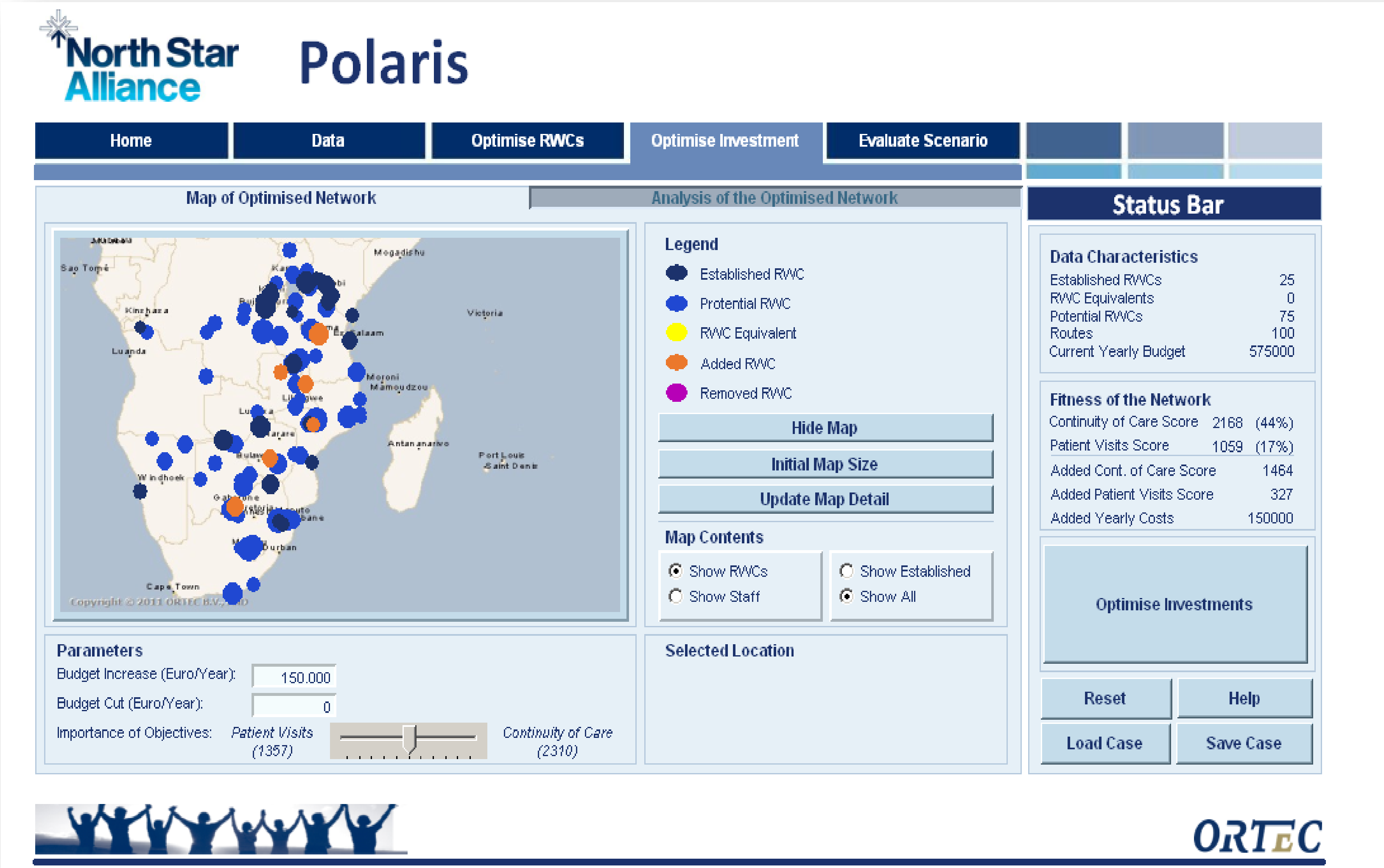
Max.  = Score 1: patient visits + Score 2: Continuity of care

Results

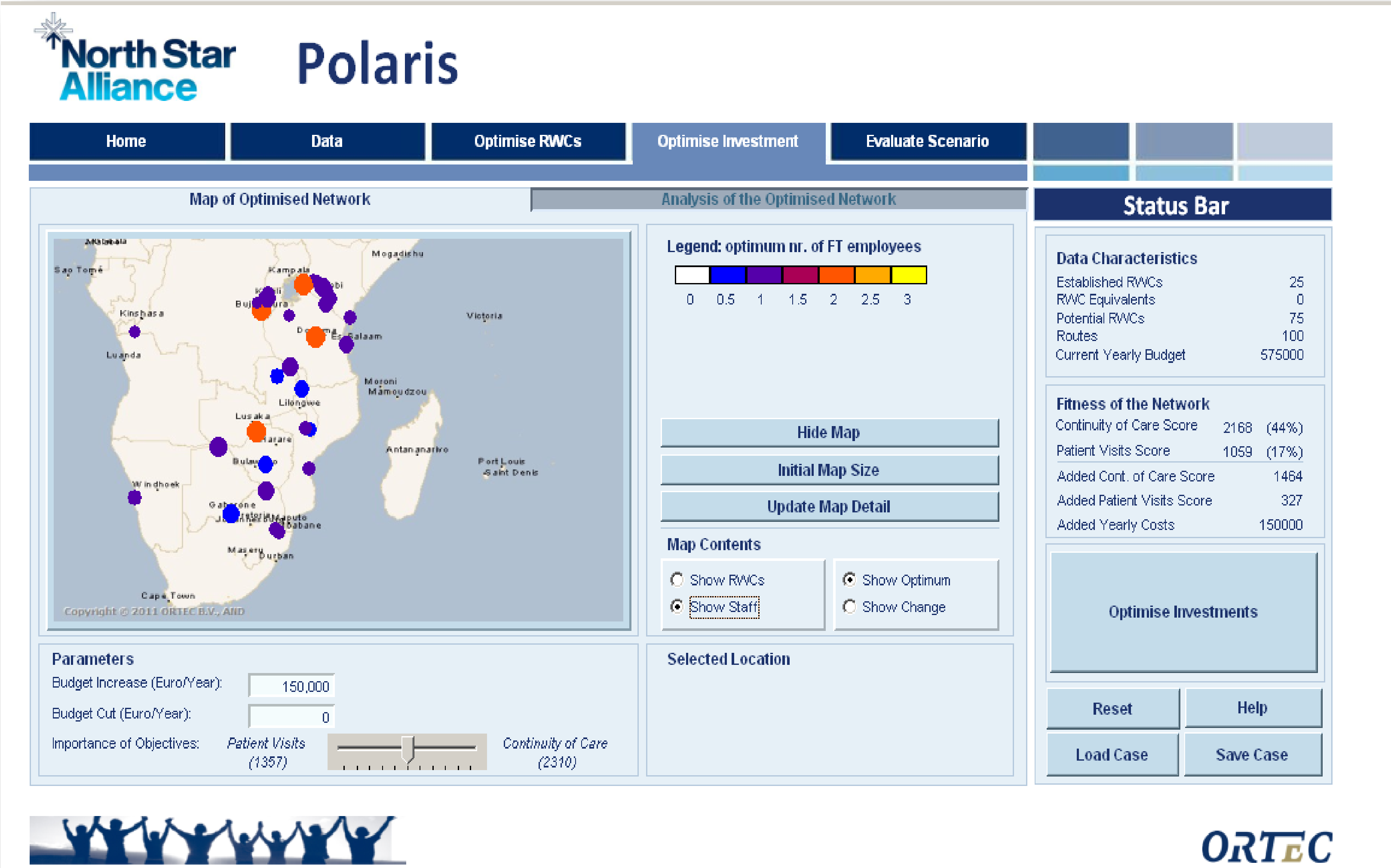
Large test case. 120 problem instances

- **Optimal solution found**
- **Average solution time: 129 seconden**

THE result


North Star Alliance
Polaris
Home
Data
Optimise RWCs
Optimise Investment
Evaluate Scenario
Map of Optimised Network
Analysis of the Optimised Network
Status Bar
Legend
Established RWC
Protential RWC
RWC Equivalent
Added RWC
Removed RWC
Hide Map
Initial Map Size
Update Map Detail
Map Contents
Show RWCs
Show Staff
Show Established
Show All
Data Characteristics
Established RWCs 25
RWC Equivalents 0
Potential RWCs 75
Routes 100
Current Yearly Budget 575000
Fitness of the Network
Continuity of Care Score 2168 (44%)
Patient Visits Score 1059 (17%)
Added Cont. of Care Score 1464
Added Patient Visits Score 327
Added Yearly Costs 150000
Optimise Investments
Reset
Help
Load Case
Save Case
Parameters
Budget Increase (Euro/Year): 150.000
Budget Cut (Euro/Year): 0
Importance of Objectives: Patient Visits (1357) Continuity of Care (2310)
Selected Location
Mogadishu
Sao Tomé
Kinshasa
Luanda
Victoria
Moroni
Mamoudzou
Antananarivo
Port Louis
Saint Denis
Windhoek
Durban
Cape Town
ORTEC

THE result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0 0.5 1 1.5 2 2.5 3
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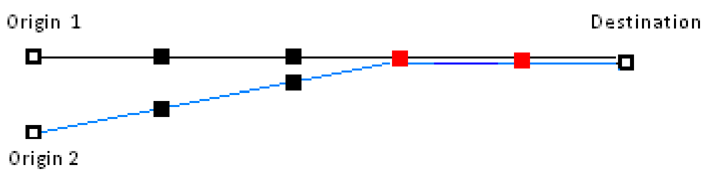
Conclusions

- Weaknesses:
  - Data
  - Simplification

Conclusions

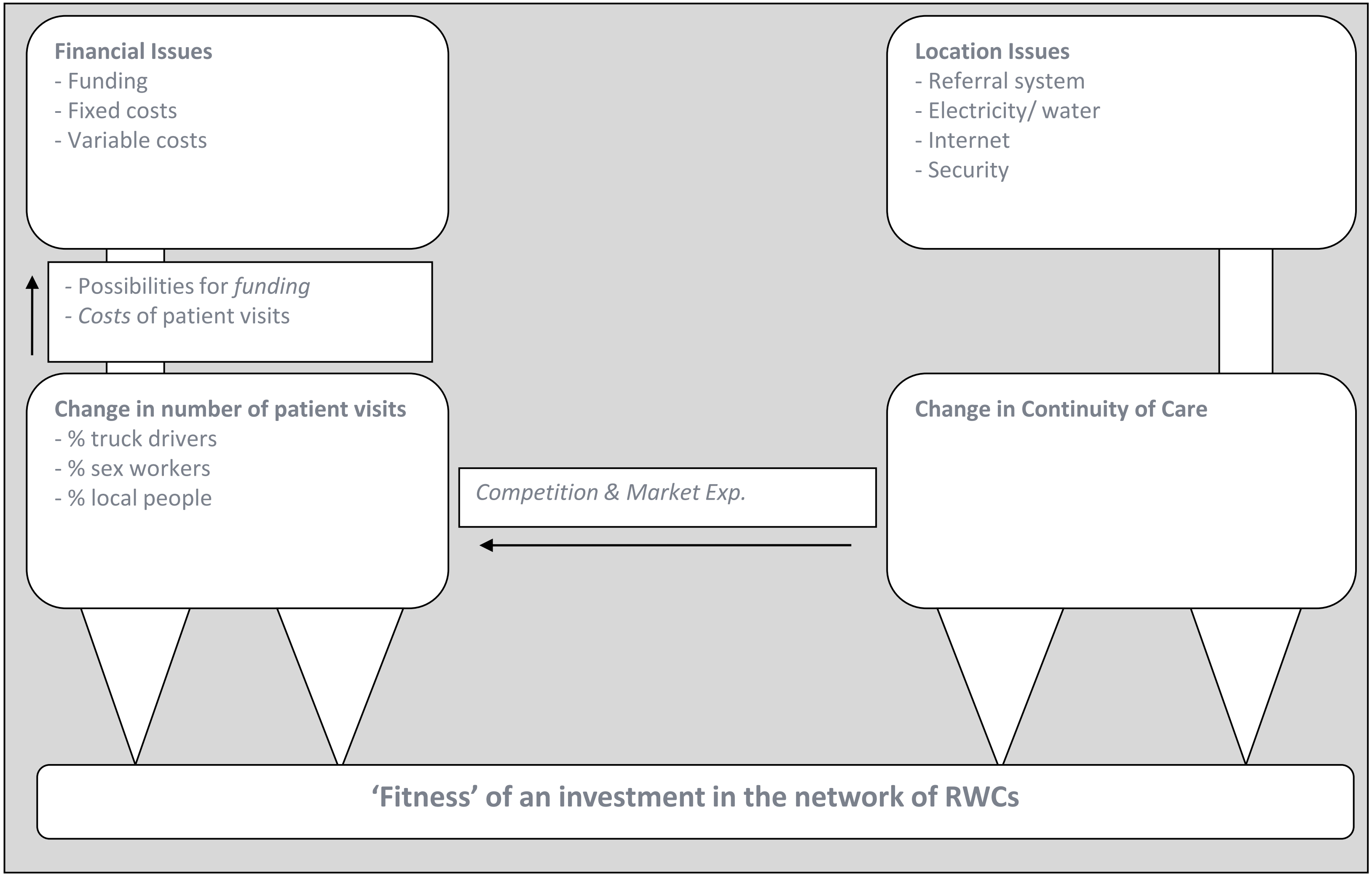
- Strengths:
  - Better investments
  - Long-term thinking enabled➔

    redundant/ ineffective investments avoided
  - Possible to ‘sell’ well-founded plans to sponsors



Additional slides

Definition of fitness of an investment



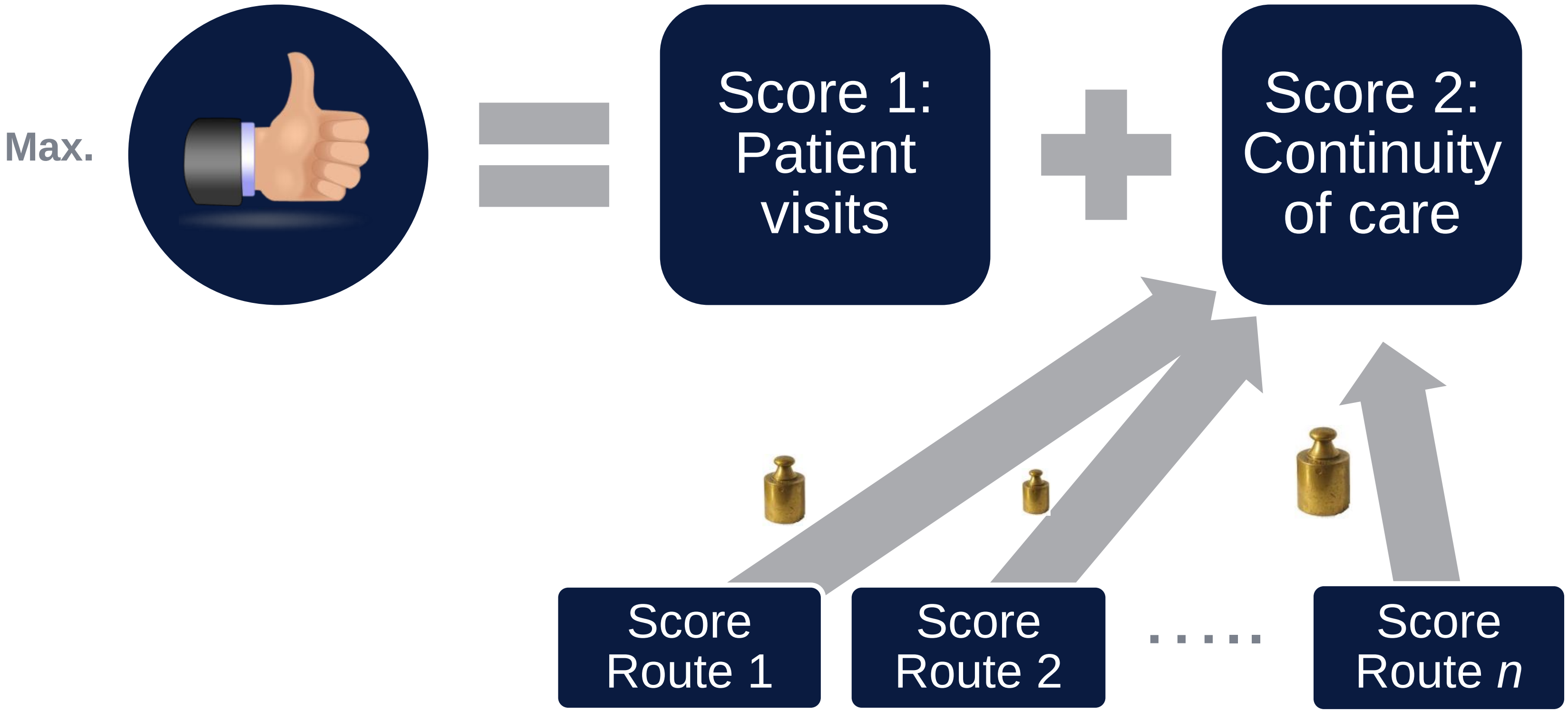
Solution

- **Mixed Integer Programming model:**

Max.  = Score 1: Patient visits + Score 2: Continuity of care

Solution

- **Mixed Integer Programming model:**



Solution

- Notation model 1:
  - Set locations $k \in K$
  - d_k = expected number of patient visits al location k
  - x_k = 1 if RWC located at location k, 0 otherwise
  - Set truck flows $q \in Q$
  - c_q = continuity of care score of flow q
- Additional notation model 2:
  - Set of numbers of employees $e \in E$
  - d_{ke} = expected number of patient visits al location k, with e employees
  - xe_{ke} = 1 there e employees work at location k, 0 otherwise

Solution

1. **Where to locate *p* new RWCs?**

Max.  $= v_1 \sum_{k \in K} x_k d_k + v_2 \sum_{q \in Q} c_q f_q$

s.t.

- Max. *p* new RWCs
- Current RWCs cannot be removed
- Definition of c_q

Solution

2. How to invest a budget *bI* in RWCs and/or employees?

Max.  $= \boxed{v_1 \sum_{k \in K} \sum_{e \in E} xe_{ke} d_{ke}} + \boxed{v_2 \sum_{q \in Q} c_q f_q}$

s.t.

- Don't exceed the budget
- Current RWCs cannot be removed
- Current employees cannot be fired
- Definition c_q

Solution

2. **How to invest a budget *bI* in RWCs and/or employees?**

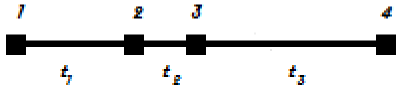
Max.

$$= \; v_1 \sum_{k \in K} \sum_{e \in E} xe_{ke} d_{ke} \; + \; v_2 \sum_{q \in Q} c_q f_q$$

s.t.

- **Don’t exceed the budget**
- **Current RWCs cannot be removed**
- **Current employees cannot be fired**
- **Definition c_q**

Solution

- How can score 2 of a route be calculated?
  - Example: 

1. Based on.:
   a) Average of t_1, t_2, t_3
   b) Maximum of t_1, t_2, t_3
   c) Variance of t_1, t_2, t_3
2. Expected RWC time:
   - $(t_1^2 + t_2^2 + t_3^2)/(2*(t_1 + t_2 + t_3))$

"A truck driver is provided with a continuum of care if (almost) always, he does not need to drive a long time before passing an RWC when he needs medical help"

Solution: summary

- Two models:
    1. Optimise (des)investments in RWCs
    2. Optimise (des)investments in RWCs and employees

- Objective: maximise:
    - Function of the expected <u>number of patient visits</u> +
    - Function of the expected <u>time to medical help when sick</u>

Results

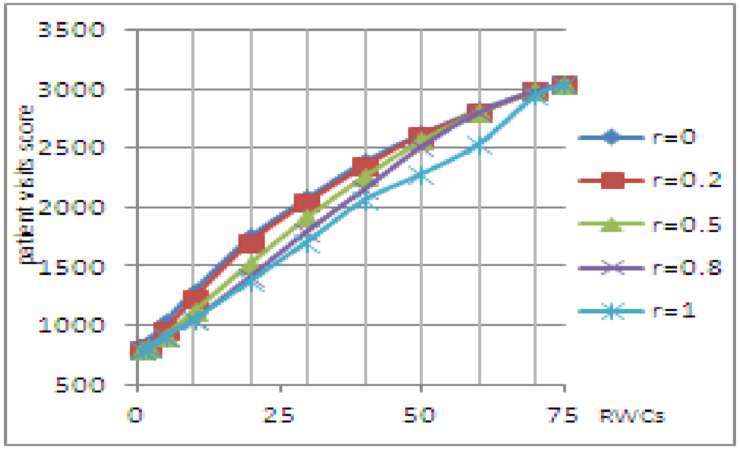


Figure 1: trade-off curve between patient visits score of a network and the number of RWCs added to that network.

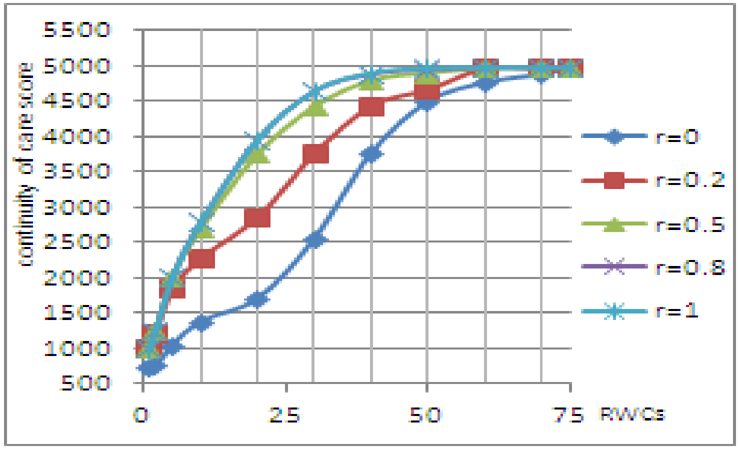


Figure 2: trade-off curve between continuity of care score of a network and number of RWCs added to that network.

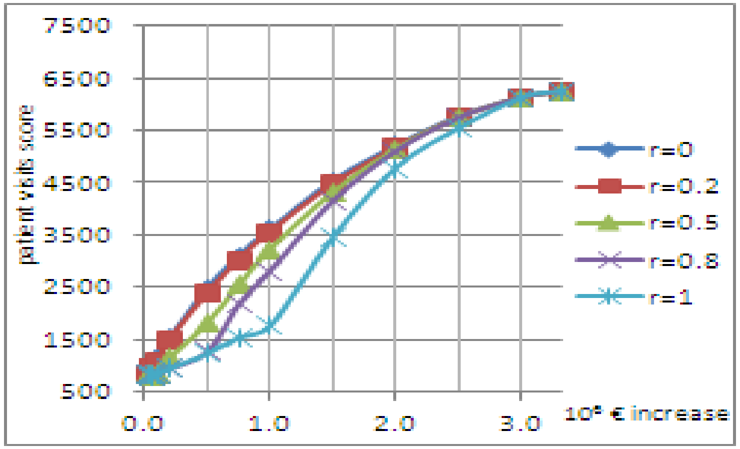


Figure 3: trade-off curve between patient visits score of a network and the budget increase in that network.

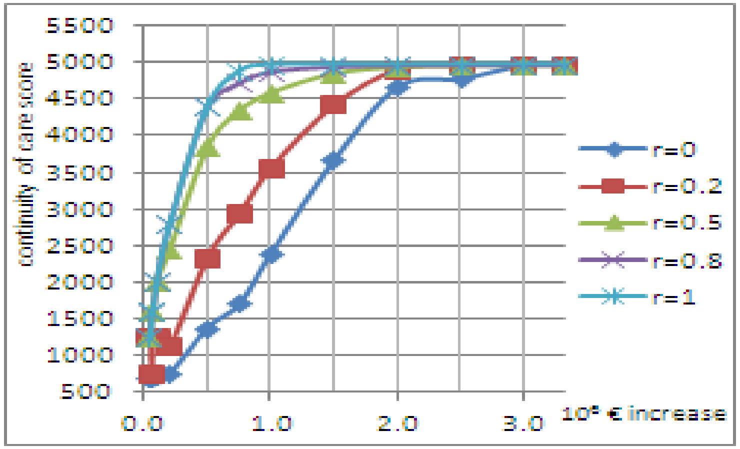
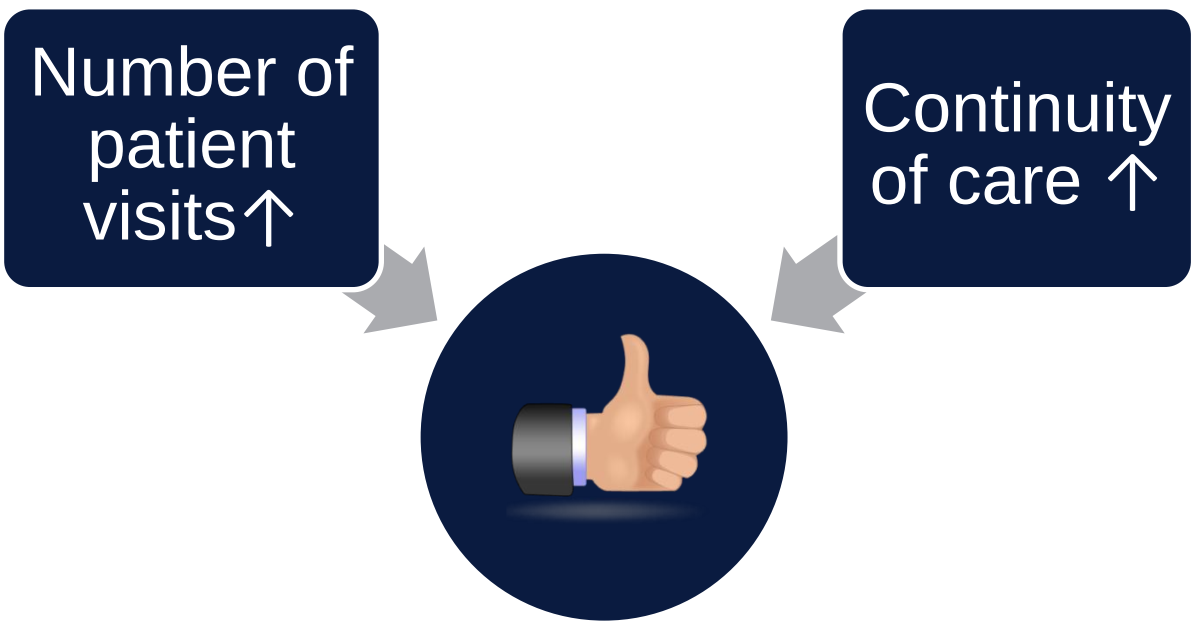


Figure 4: trade-off curve between continuity of care score of a network and the budget increase in that network.

Conclusions

- Weaknesses:
  - Data
  - Simplification



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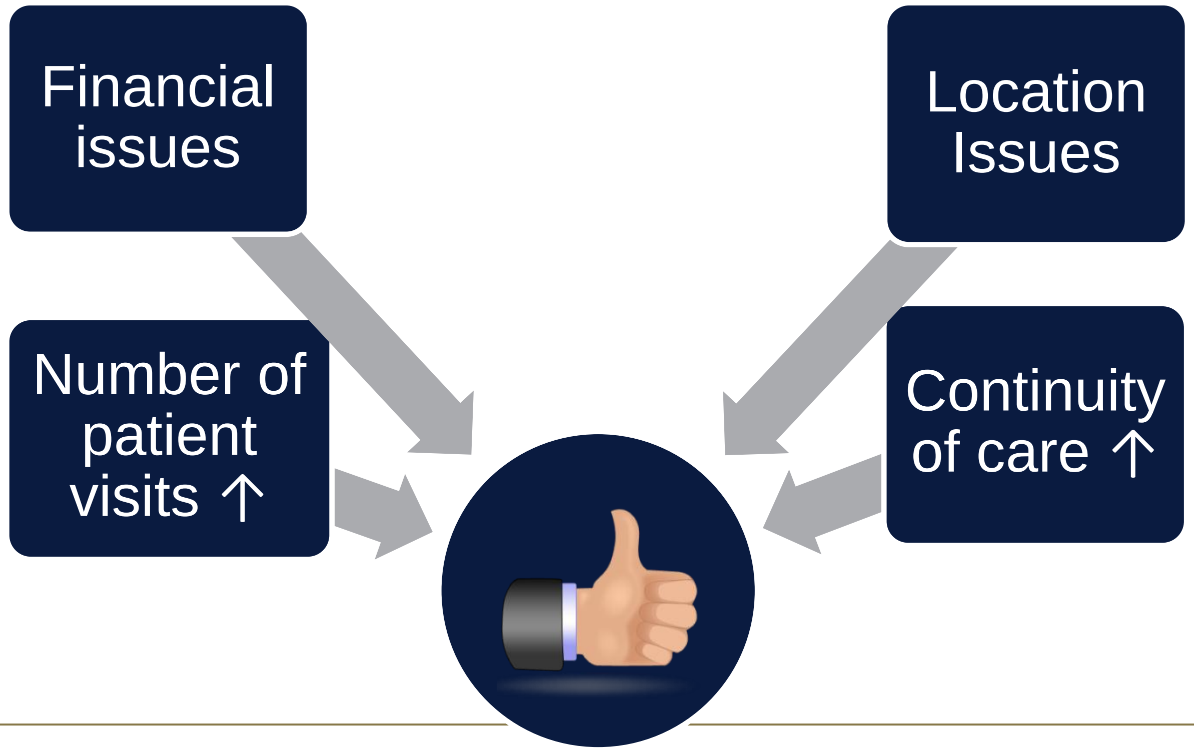
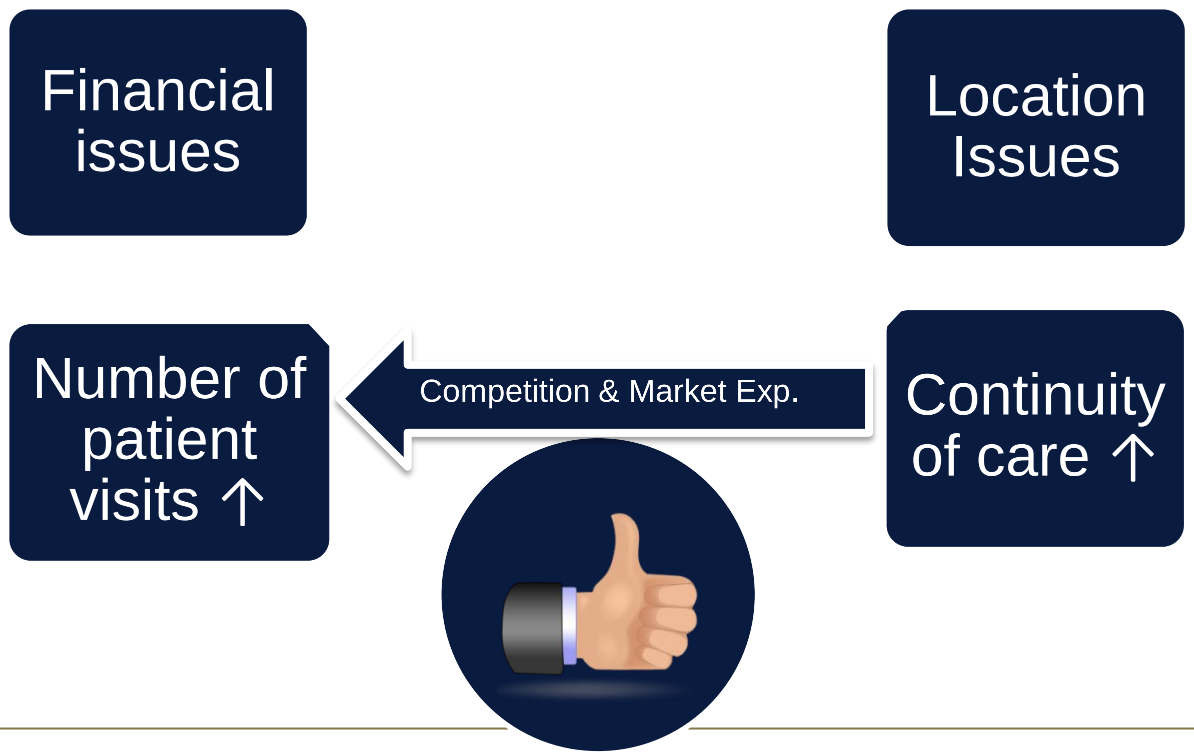


Conclusions

- **Weaknesses:**
  - **Data**
  - **Simplification**



Weaknesses

How to deal with:

- Simplification: compare the ‘best’ solutions
- Sensitivity of optimum wrt parameters: play around with parameter values
- Bad data:
    - Worst case scenarios: what if…
    - If stakes are high: invest more in data gathering

Weaknesses

How to deal with:

- Decreasing marginal benefits of investments:
  - 1: Find better potential investments (strategically located, busy locations)
  - 2: Express the benefits of an investment in money. Stop investing when costs > benefits

Logical optimal investments

New RWCs at locations…

- **With many potential patients**
- **That are strategically located**

Mix between 2 extremes:

- **Only invest in new employees (cheap way to increase nr. of patient visits)**
- **Only invest in new RWCs (optimal in terms of continuity of care)**

Example better investment

Problem: optimise locations of 5 new RWCs

1. Only patient visits (i.e. current investment strategy):
    - Patient visits: +44%
    - Continuity of care: +50%
2. Patient visits & continuity of care:
    - Patient visits: +24%
    - Continuity of care: +187%

Place in literature

1. Location Allocation Models
2. Flow Covering Models
3. Multi Coverage Models, with fractional coverage (not binary coverage)

Related applications:

- Billboard locations along highways
- Flow Refuelling Location Model