GAMA Technical Group
Webinar

21st January 2016
#GAMAnresiliencen
Agenda

1. Welcome and introductions
2. Update on programme - Stephen Passmore
3. Global Update - Catherine Allinson
4. Update on model development - ICL
5. Use case 1st review - Rembrandt Koppelaar
6. Use case discussion
7. AOB
8. Next steps and Close

http://ecosequestrust.org/GAMA
resilience.io programme

- Part of Future Cities Africa to develop tools to future-proof cities
- Data collection
- WASH Prototype development
- Use Case Development
- Engagement
- Demonstration - May 2016
Global Update

- Sampson Madana started in-country work as Chair of the GTG and working with technical review panel


- Applied for funding to continue our work with the GTG in Accra from DfID OpenIDEO; Bloomberg FiRe, Wellcome Trust UK - now seeking private sector partners

- Attended the official launch and first AGM of the UN Office for Disaster Risk Reduction (UNISDR) [RISE Initiative](https://riseinitiative.org) with private sector partners
Global Update

- Building a Urban Development and Investment Fund to support resilient development in cities
Preliminary outcomes of the agent-based modelling and resource network optimisation for the WASH sector in GAMA, Ghana

Resilience.IO platform

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21 January 2016
Outline

• Introduction and context (Xiaonan Wang)
  • WASH use case 1
  • Role of modelling and simulation

• Agent-based modelling (Xiaonan Wang, Koen H. van Dam)
  • What and why
  • Applications in GAMA WASH simulation

• Optimisation (Harry Triantafyllidis)
  • What and why
  • Preliminary/illustrative outcomes Use Case 1

• Towards the final model for the WASH sector in GAMA (Rembrandt Koppelaar)
  • Next steps
  • Interviews and review of use cases
  • Visual presentation

• Discussion
Introduction and context

Speaker: Dr Xiaonan Wang
WASH Challenges – Use case 1

- Three use cases were selected previously
- First focus on Use Case 1:

Assess outcomes of ongoing WASH projects and gaps towards meeting macro-level targets for planning

Input
- Capacities and time frame of all ongoing projects
- Targets and goals from local, national policies and international agreements

Projects & Targets
- 5 to 20 years of population, economic status, and migration
- Socio-economic scenarios

Model use
- Calculate combined effect of on-going projects when fully completed to targets
- Estimate gaps remaining

Output
- Costs/benefits from successful completion
- Additional effort and possibilities to meet targets
Idea: use a simulation model of a synthetic population to experiment with different scenarios to generate demand profiles, which can then be used to optimise the technologies and networks with key performance metrics.
Agent-based model of WASH sector in GAMA

Speaker: Dr Xiaonan Wang, Dr Koen H. van Dam
Definition of agent-based modelling

Agent-based modelling is a computational method that enables a researcher to create, analyze, and experiment with models composed of agents that interact within an environment.

(Nigel Gilbert, 2007)
Purpose of the model

Stage 1
Simulate population of GAMA

Stage 2
Estimate demand for water resources based on activities of the population

Stage 3
Provide long-term socio-economic scenarios
Agent activities (example)

\[ AP_i = \{(ACT_j, MDT_j, SD_j, PD_j)\} \]

- \( ACT_j \): Activity \( j \)
- \( MDT_j \): Mean departure time
- \( SD_j \): Standard deviation
- \( PD_j \): Probability of departure

(Activity depend on agent characteristics)
Agent characteristics

- Gender
- Age
- Work force status
- Income status
- Home/ Work location

Socio-economic/Spatial

Access to infrastructure

- Drinking water
- Non-Drinking water
- Toilet

Agent activities

Land use
Synthetic population (1/2)

- Agents are generated in a stochastic process based on real data collected for GAMA, leading to a representative synthetic population (~0.1% of real population)

- Socio-economic
  - Gender (male or female)
  - Age (0-14 years or 15+)
  - Work force status (Employed / Not active or unemployed)
  - Income status (Low income / Medium income / High income)

- Spatial
  - Home location (point in district/MMDA)
  - Work location, for those economically active, based on distance from home
Synthetic population (2/2)

- Access to infrastructure
  - **Drinking water** (private pipe access / public tap or stand pipe / protected decentralised source / unprotected decentralised source / tanker and vendor provided / sachet water / bottled water) → simplified to private/non-private access
  - **Non-drinking water** (private pipe access / public tap or stand pipe / protected decentralised source / unprotected decentralised source / tanker and vendor provided) → simplified to private/non-private access
  - **Toilet** (Water closet / Kumasi VIP / Pit Latrine / Public Toilet / Bucket or Pan Latrine / No facilities)

- Household demands are dependent on:
  - Access to infrastructure
  - Income level
  - Time of day (i.e. activities)
First model (shown in August 2015 webinar)
Model development – Progress update

Expansions implemented:
- Detailed water use and flow from human activities (modelled)
- Waste water flow
- Commuting (basic)
- Data collection per MMDA

Work in progress:
- Non-residential demands
- Pipelines and sewage flows
- Toilet use
- Commuting (detailed)
- Incorporate long-term population and economic scenarios
Screenshot agent-based simulation
Screenshot agent-based simulation

dense agent population
Example outcomes

- Drinking water demand profile per MMDA over 24 hour period

- Total potable water demands (annual): 31.9 million m$^3$

  → these demands feed into the RTN for optimisation
Example outcomes

- Waste water profile per MMDA over 24 hour period

- Total waste water generation (annual): 814.1 million m$^3$

→ these demands feed into the RTN for optimisation
Resource-Technology Network optimisation

Speaker: Dr Harry Triantafyllidis
Idea: use a simulation model of a **synthetic population** to experiment with different scenarios to generate **demand profiles**, which can then be used to **optimise the technologies and networks** with key **performance metrics**.

**Approach:** linking ABM and RTN
Preparing the data

- Current technology in place
- Demands from ABM
- Technical specifications
- Flow costs, capital expenditure, operational costs, import values, emissions
- Pipe network (?) across districts
- MMDAs coordinates
How the optimization works

- Production rates – satisfy demands
- Technology balance – investments
- Import resources?
- Resource surplus – better to flow it around or build infrastructure?

Minimize cost/CO$_2$ emissions while treating the network as a whole
Technological infrastructure - potable water

Source Water Treatment Systems:
- Central Source Water Treatment
- Desalination Plant
- Boreholes with pipes
- Protected wells & springs

Drinking Water Systems:
- Bottled water plant
- Sachet drinking water

Distribution networks:
- Potable water pipe network
Technological infrastructure - wastewater

Large wastewater treatment:
- UASB wastewater treatment
- Waste stabilisation ponds
- Aerated lagoons

Smaller wastewater treatment:
- activated sludge
- anaerobic biogas
- aerobic treatment (biokube)
- sludge polymer separation & drying

Distribution networks:
- Sewage pipe network
Resources in network

1. raw source water
2. electricity
3. labour hours
4. potable water
5. sludge
6. pot distributed water
7. carbon dioxide
8. influent wastewater
9. raw waste water
10. drink water sachet
11. treated effluent
12. influent faecal sludge
Characteristics of test model

- 15 MMDAs
- 2-year simulation (not fixed) with ability to split a single day for 5 periods, each reflecting different demands
- 17 tech types, 12 resources
- Pipe connections
- Pre-allocated tech units on base year (2010)
- Optimize capex/opex/CO₂
- Satisfy % of demands in potable water and treated waste water
Preliminary outcomes of use case 1
Example – USE CASE 1 - work in progress

Detailed implementation: The formulated model has 5,191 constraints and 36,455 variables

20% of demands in potable water and treated waste water with existing infrastructure + investments:

- KPI('capex'.2010) = ~16.8 billion USD
- KPI('opex'.2010) = ~ 36 million USD
- KPI('CO₂'.2010) = ~8k tons / m³

70%:

- KPI('capex'.2011) = 0 USD
- KPI('opex'.2011) = ~ 127 million USD
- KPI('CO₂'.2011) = ~ 29k tons / m³
Automated Visualized output

MMDA’s on map
• Associated optimal flows
• Geo-localized
• Connectivity
• Bandwidth of flow visualized with the width of each edge
• MMDA’s size scaling up with demands
Provide insights under various input scenarios and for specific targets

- Implement current status of infrastructure and experiment with costs / alternative tech types
- Insight where to build new infrastructure for cost reduction
- Let the model figure out from scratch the optimal allocation of the network and associated resource flows
- Employ long-term provision depending on different future policies or needs (ABM-RTN re-feed)
- Project technical importance of any component (predict impact of flaws / breakdowns in network)
- Calculate environmental impact of decisions!
Next steps use cases and stakeholder engagement

Speaker: Rembrandt Koppelaar
Next Steps

• Refine and improve current Use Case 1, build functionality for Use Case 2 (improved water) and 3 (toilet use)
  • Refine technology selection for calculation CAPEX and OPEX
  • Add functionality for water and sewage pipe system expansion
  • Simulation of toilet use during the day

• Integrate financial charges for pipe connections, water use and toilet use by simulated population based on PURC tariffs, public, private fees
  • How much does the infrastructure use cost the population, and what revenues are generated per MMDA?
Next Steps

• Build capability to include scenarios for population and household demographics change to 2030
  • What infrastructure is needed and what is the cost to respond to demographic changes and associated water demands, toilet usage, and wastewater treatment needs?

• Include rainfall patterns and agricultural water demands
  • How do changes in rainfall and affect water needs, and what would be the implication of increased irrigation on (waste)water treatment?
Interviews and Review of Use Cases

- MLGRD, MWRWH, AMA, TEMA, Zoomlion, CWSA

Key Points:

- Affordability → In neighbourhoods income of population is mixed, it is challenging to know if new infrastructure is affordable for residents

- Toilet categories → Include toilets at schools, marketplaces, bus stops

- Floating population → Many people moving in and out of districts in daytime posing large challenges on infrastructure (450,000 estimates for TEMA)
Decide on visual presentation

- Presentation of data to make interpretation easier and faster
- Examples from reports by MLGRD, MWRWH, CWSA:

Line charts:  
Pie charts:  
Bar charts with table:
Decide on visual presentation

Sankey Diagram of Flows: Example estimates for Ga South 2010 in m$^3$/day (2012 district boundaries)
Decide on visual presentation

Horizontal stacked bar charts for categories per district

- Use of different water sources (improved / unimproved)
- % discharge of liquid wastes and human excreta
- % of waste-water treated per district
Decide on visual presentation

Map with Flows between districts: Example flows of potable water from treatment based on main water trunk lines
Preliminary outcomes of the agent-based modelling and resource network optimisation for the WASH sector in GAMA, Ghana

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Thank you