GAMA Technical Group
Webinar

21st January 2016
#GAMAresilience

the ecological
sequestration trust

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

the ecological sequestration trust

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

the ecological sequestration trust

Global Update

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

- COP21 and the Paris agreement – showcased our inspiration video at the ArtCOP stage http://www.artcop21.com/soil-to-sky-film-the-scological-sequestration-trust/

- 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) R!SE Initiative with private sector partners

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Global Update

- Building a Urban Development and Investment Fund to support resilient development in cities

Centre for Process Systems Engineering

Imperial College London

Preliminary outcomes of the agent-based modelling and resource network optimisation for the WASH sector in GAMA, Ghana

Resilience.IO platform

Harry Triantafyllidis, Xiaonan Wang,
Rembrandt Koppelaar and Koen H. van Dam

Department of Chemical Engineering, Imperial College London, UK
IIER – Institute for Integrated Economic Research

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

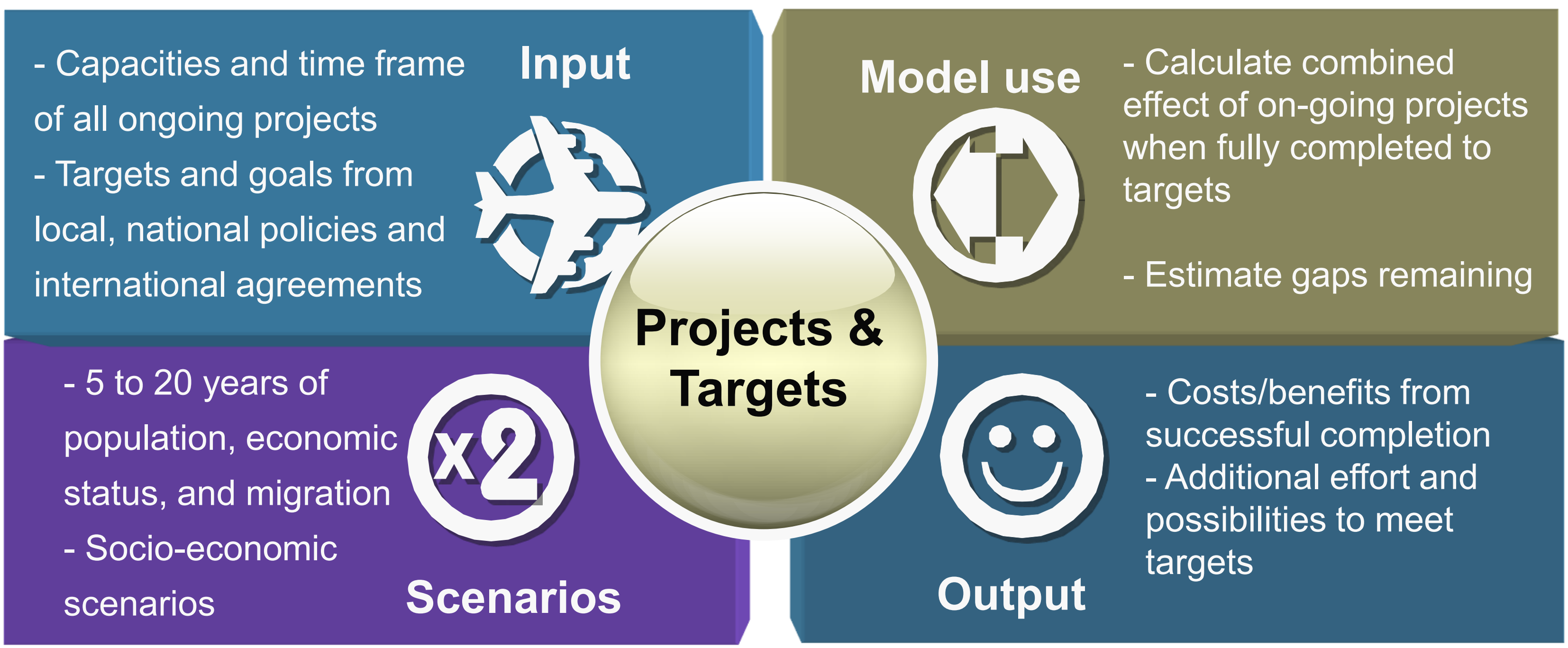
Introduction and context

Speaker: Dr Xiaonan Wang

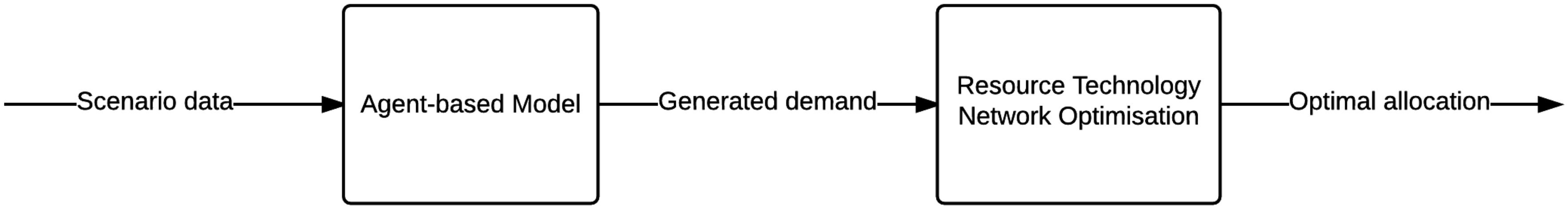
WASH Challenges – Use case 1

- *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



Approach: linking ABM and RTN



- *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

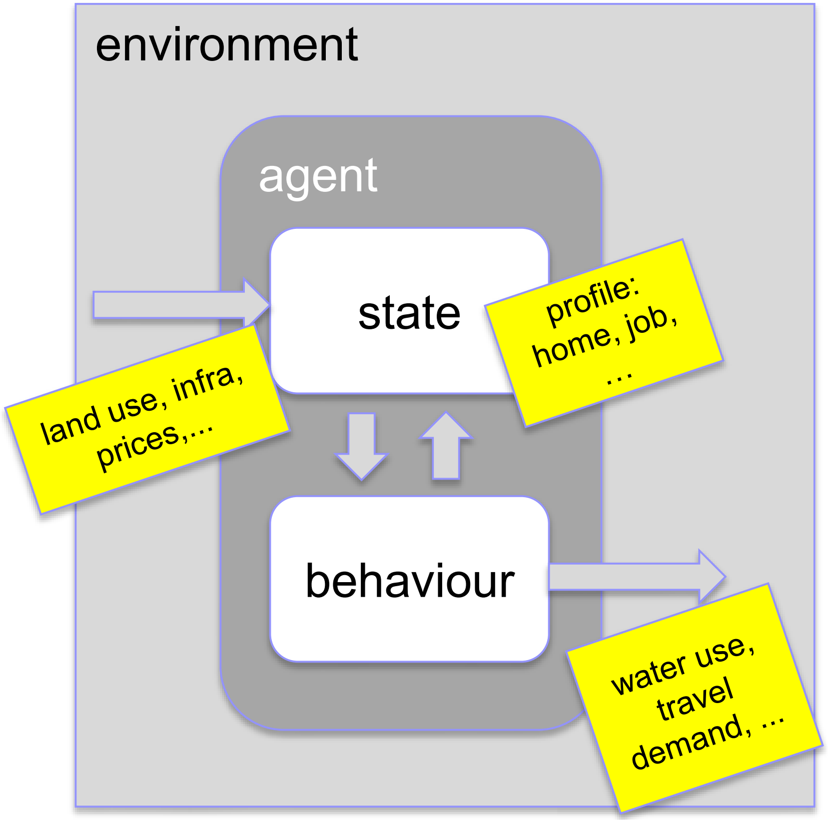
Speaker: Dr Xiaonan Wang, Dr Koen H. van Dam

Definition of agent-based modelling

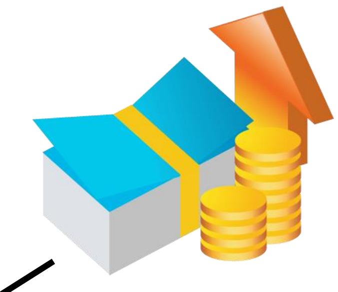
Agent-based modelling

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 3

Provide long-term socio-economic scenarios

Stage 2

Estimate demand for water resources based on activities of the population

Stage 1

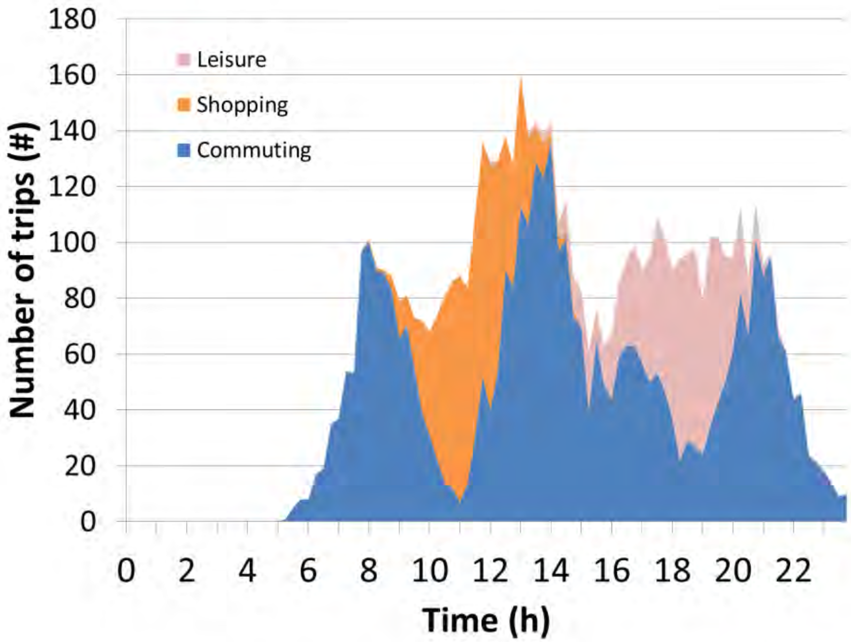
Simulate population of GAMA

Agent activities (example)

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

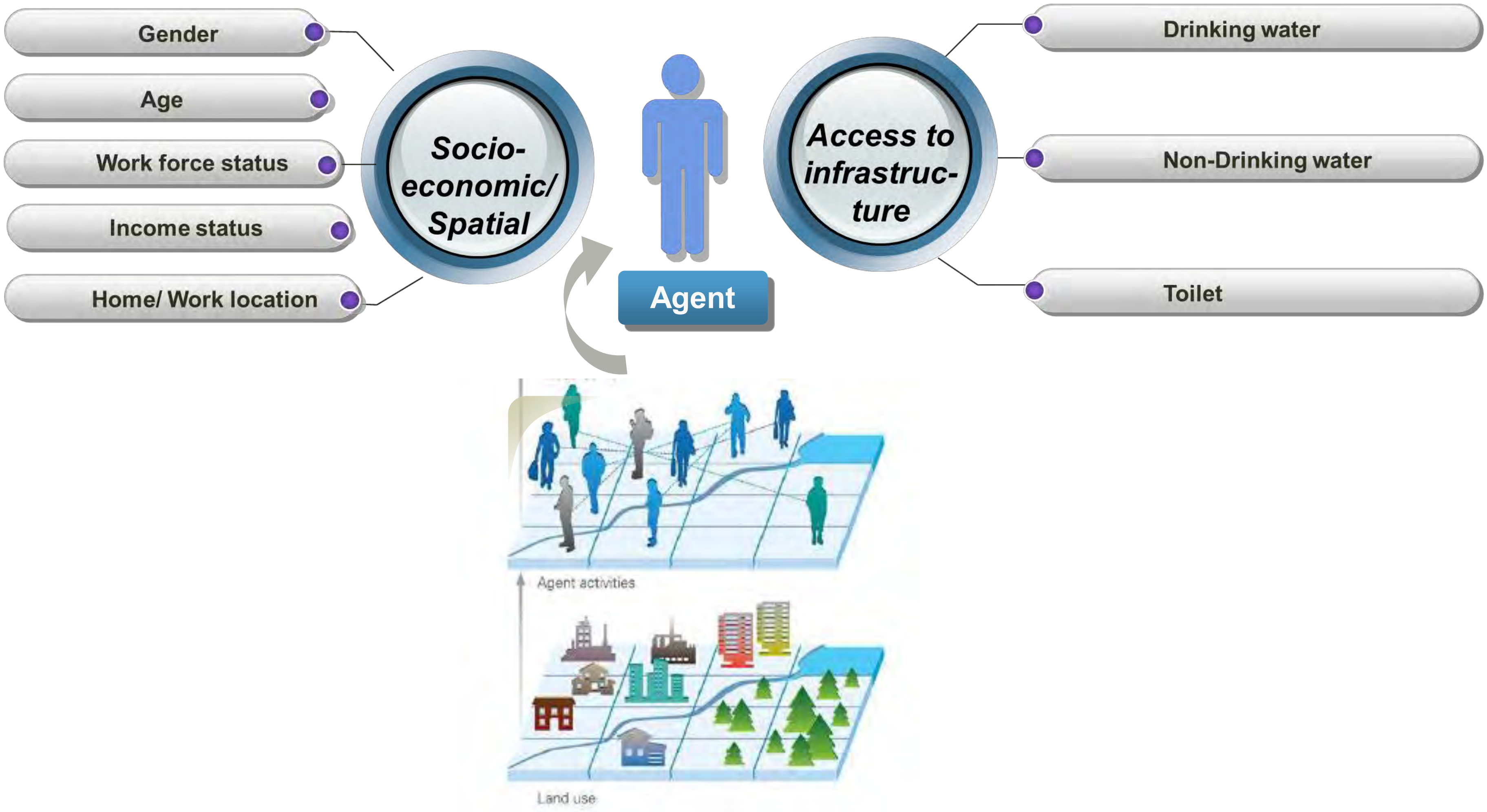
ACT_j	: **Activity j**
MDT_j	: **Mean departure time**
SD_j	: **Standard deviation**
PD_j	: **Probability of departure**

Activity Schedule $\{(ACT_j, MPT_j, SD_j, PD_j)\}$			
Worker	(work, 8, 1, 1.0)	*Non-Worker*	(work, 9, 1, 0.1)
	(shopping, 13, 0.5, 0.3)		(shopping, 11, 0.5, 0.8)
	(work, 15, 0.5, 1.0)		(work, 14, 1.0, 0.0)
	(home, 17, 1.0, 0.7)		(home, 13, 05, 0.8)
	(leisure, 18, 1.0, 0.3)		(leisure, 17, 1.5, 0.5)
	(home, 21, 1.0, 1.0)		(home, 21, 1.5, 1.0)



(Activities depend on agent characteristics)

Agent characteristics



Synthetic population (1/2)

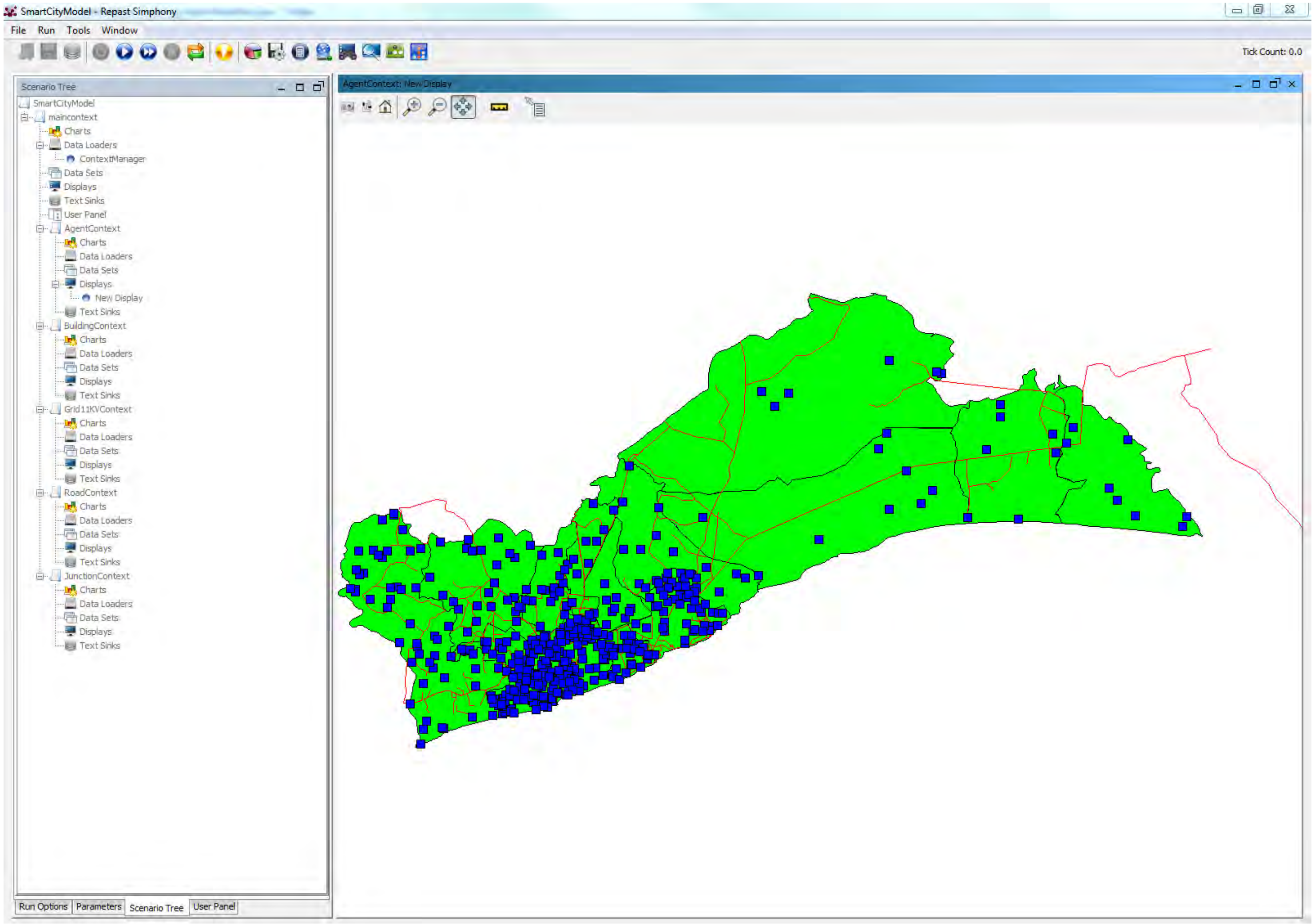
- Agents are generated in a stochastic process based on real data collected for GAMA, leading to a representative synthetic population (~0.1% of real population)

- 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

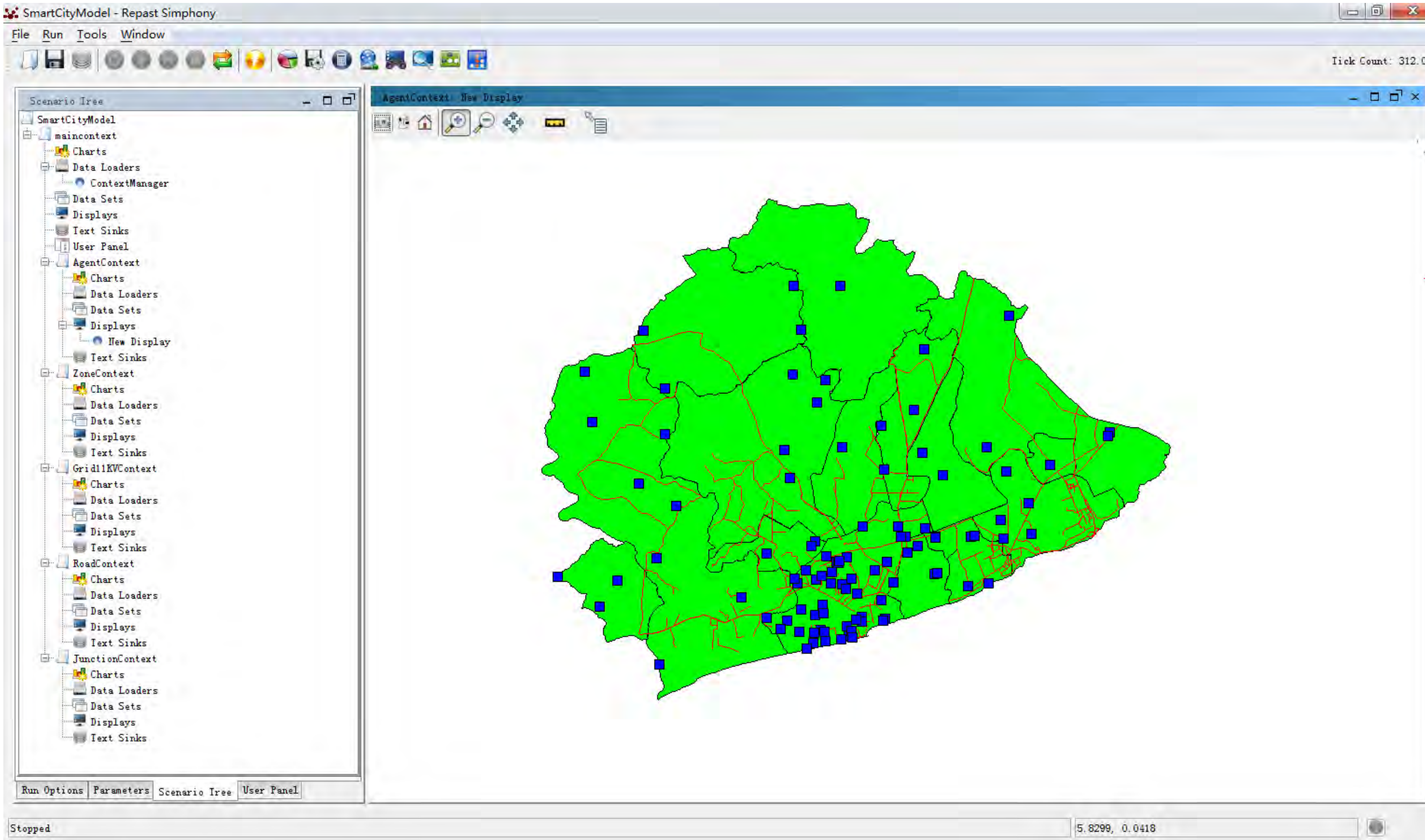
Expansions implemented:

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

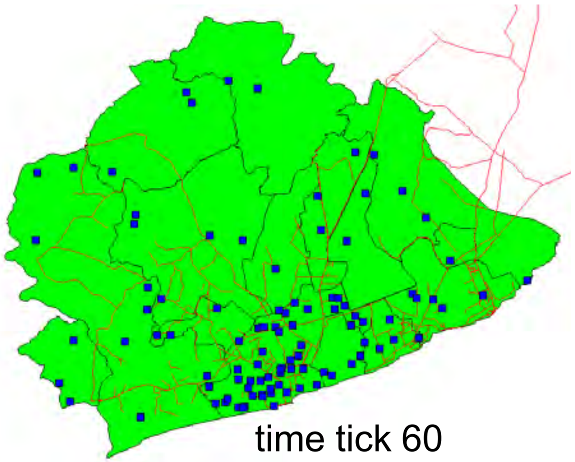
Work in progress:

- Non-residential demands
- Pipelines and sewage flows
- Toilet use
- Commuting (detailed)
- Incorporate long-term population and economic scenarios

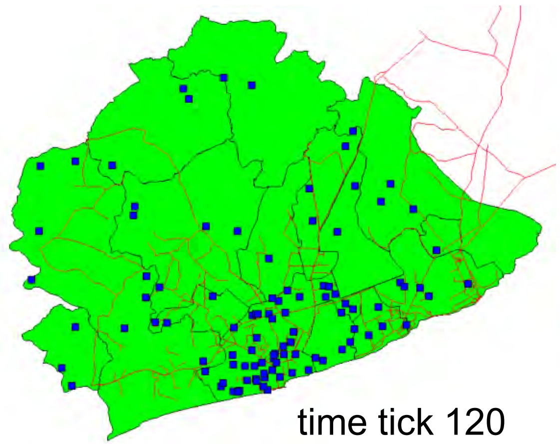
Screenshot agent-based simulation



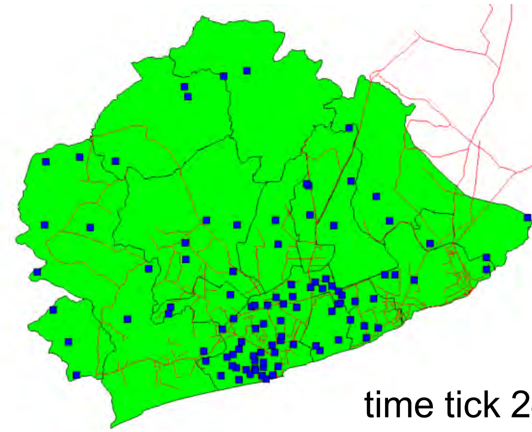
Screenshot agent-based simulation



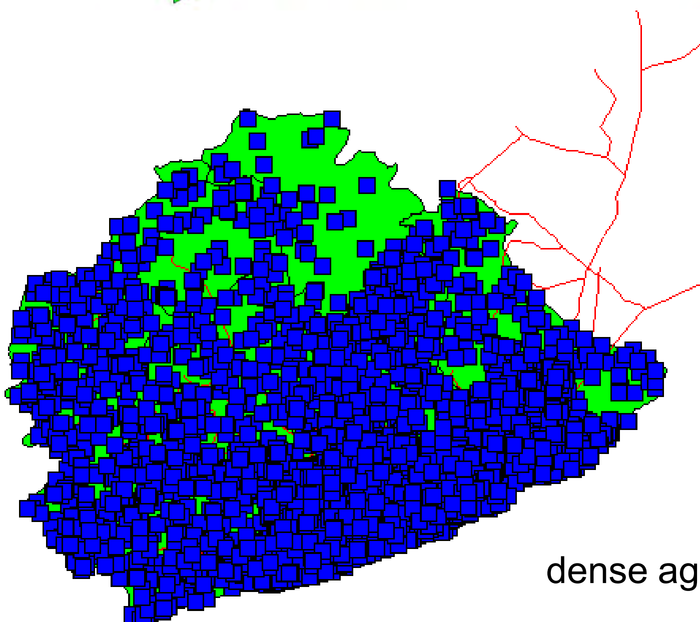
time tick 60



time tick 120



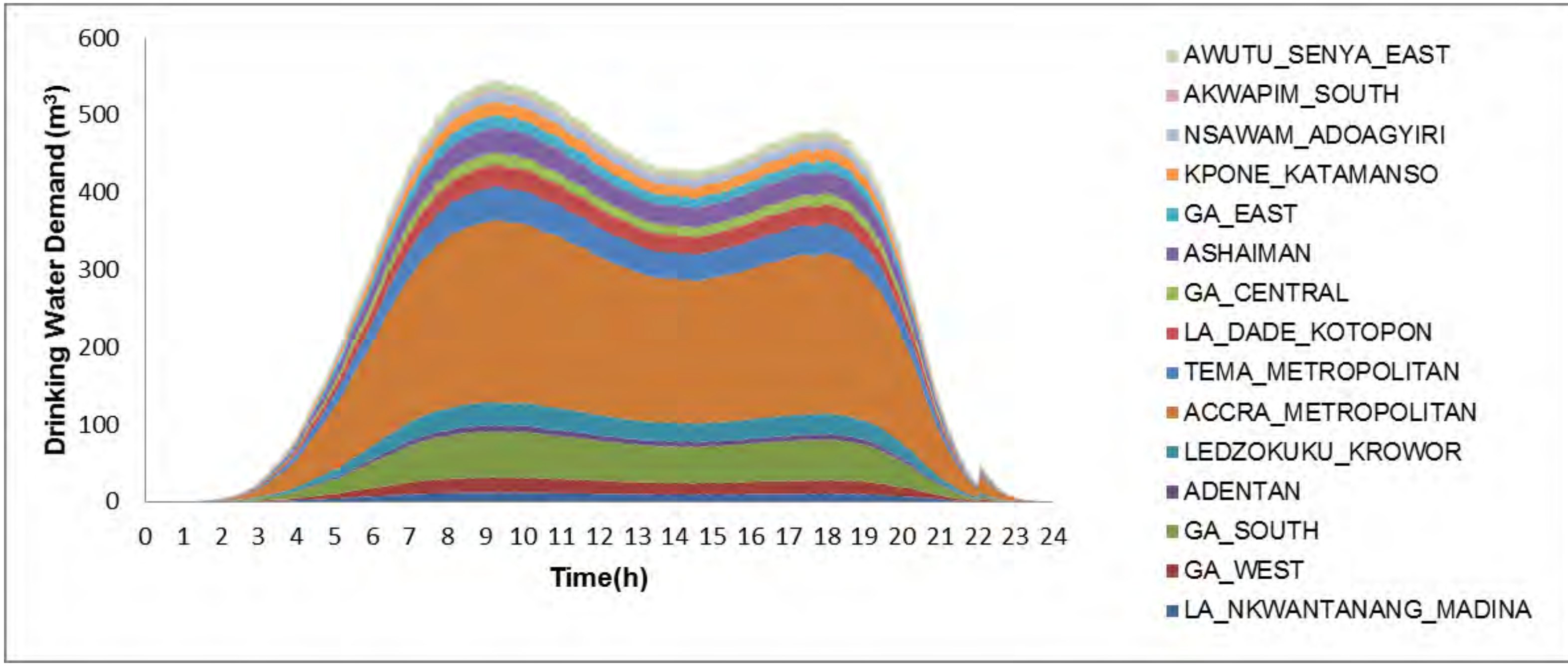
time tick 240



dense agent population

Example outcomes

- Drinking water demand profile per MMDA over 24 hour period

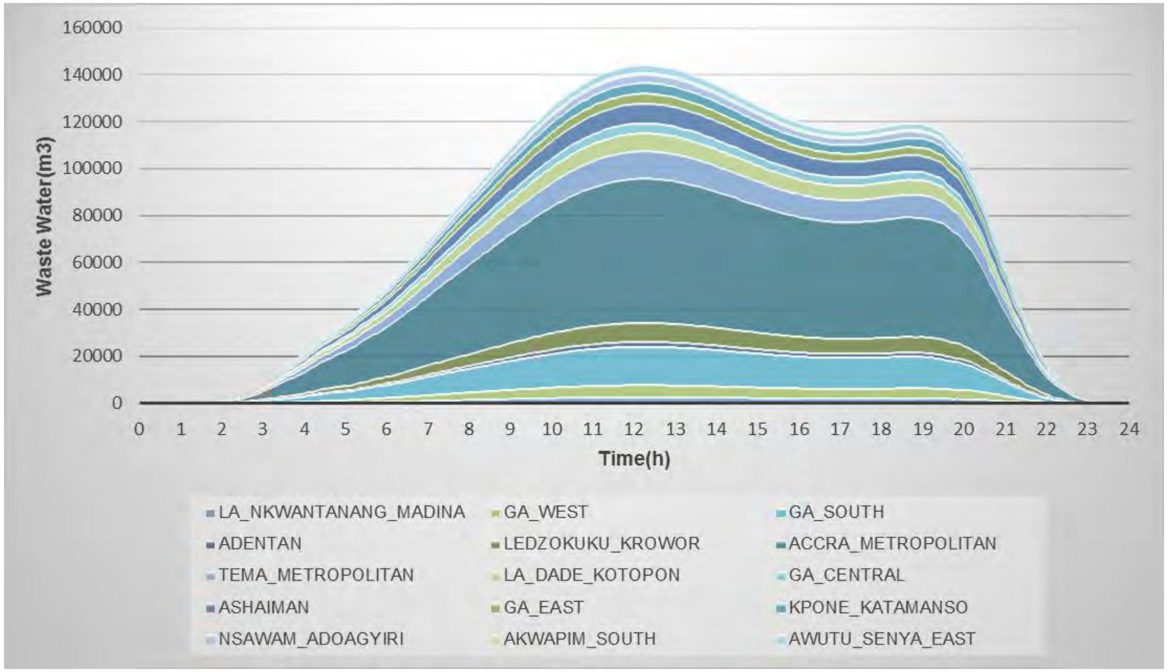


- Total potable water demands (annual): 31.9 million m^3

→ these demands feed into the RTN for optimisation

Example outcomes

- Waste water profile per MMDA over 24 hour period



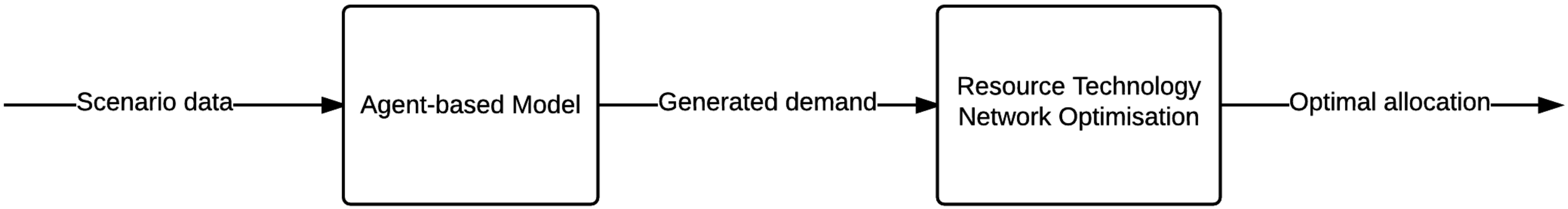
- Total waste water generation (annual): 814.1 million m^3

→ these demands feed into the RTN for optimisation

Resource-Technology Network optimisation

Speaker: Dr Harry Triantafyllidis

Approach: linking ABM and RTN



- *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***

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

Raw Water → **Source Water Treatment Systems:** → Potable water

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

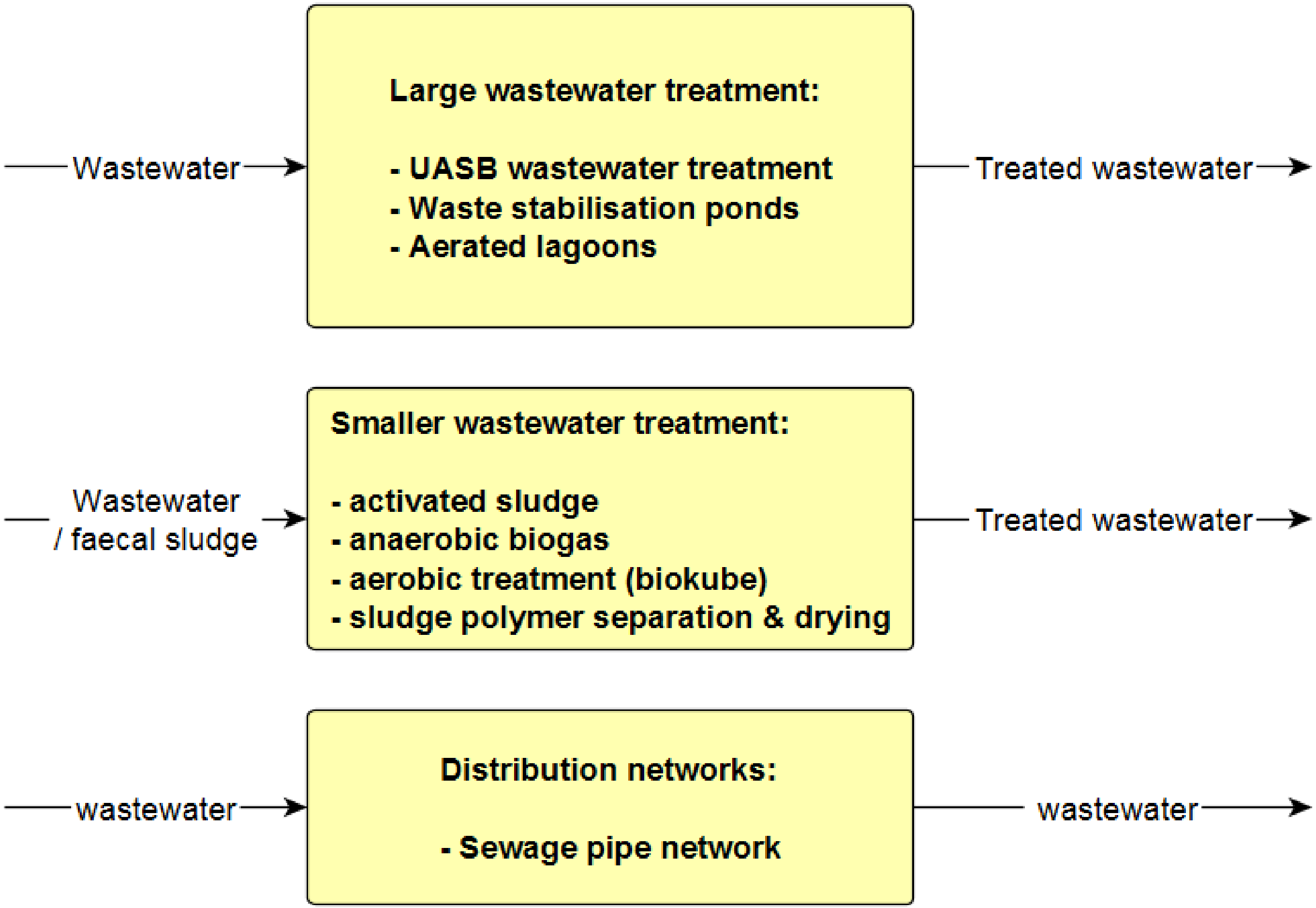
Raw Water → **Drinking Water Systems:** → Potable water

- **Bottled water plant**
- **Sachet drinking water**

Potable water → **Distribution networks:** → Potable water

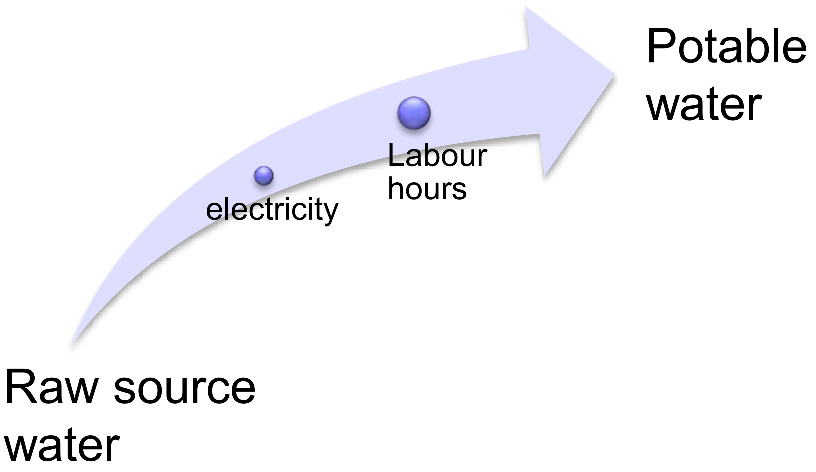
- **Potable water pipe network**

Technological infrastructure - wastewater



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/CO_2
- 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('CO_2'.2010) = ~8k **tons / m^3**

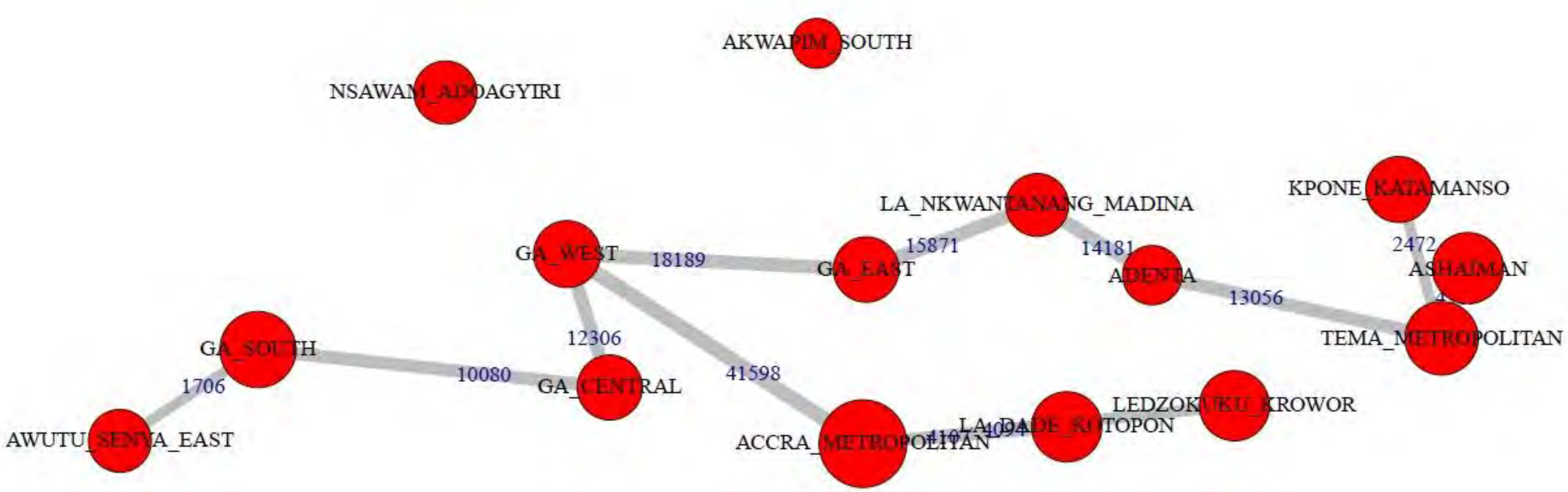
70% :

- KPI('capex'.2011) = 0 **USD**
- KPI('opex'.2011) = ~ 127 million **USD**
- KPI('CO_2'.2011) = ~ 29k **tons / m^3**

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

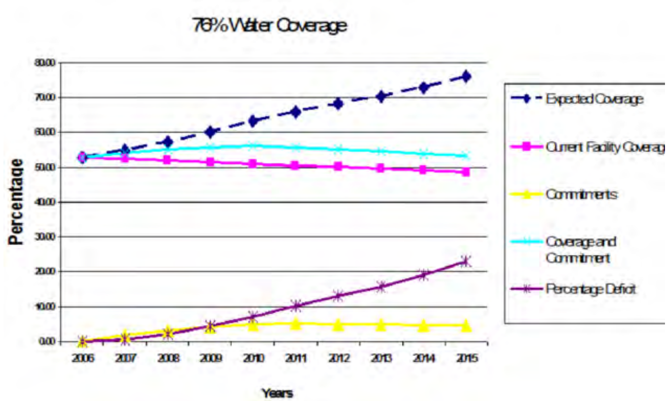
Key Points:

- 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)

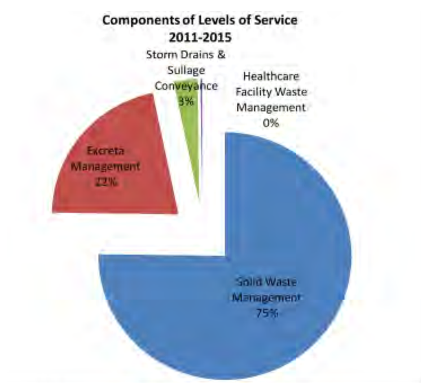
Decide on visual presentation

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

Line charts:



Pie charts:



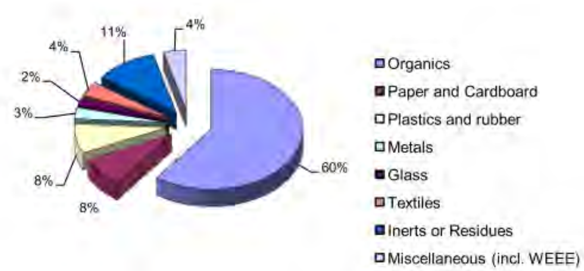
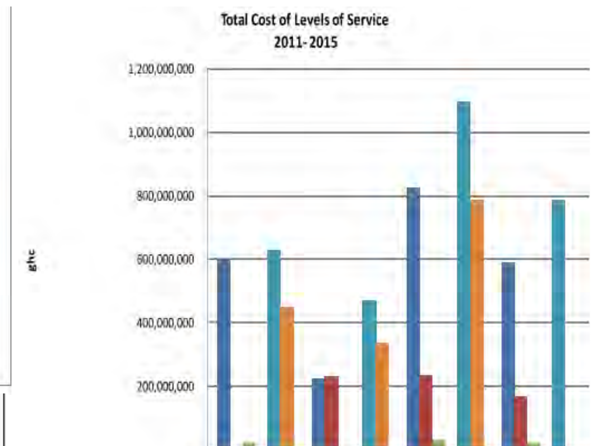


Figure 3.2: Average Composition of Solid Waste Stream, GAMA. Baseline Surveys, MMDAs, 2008.

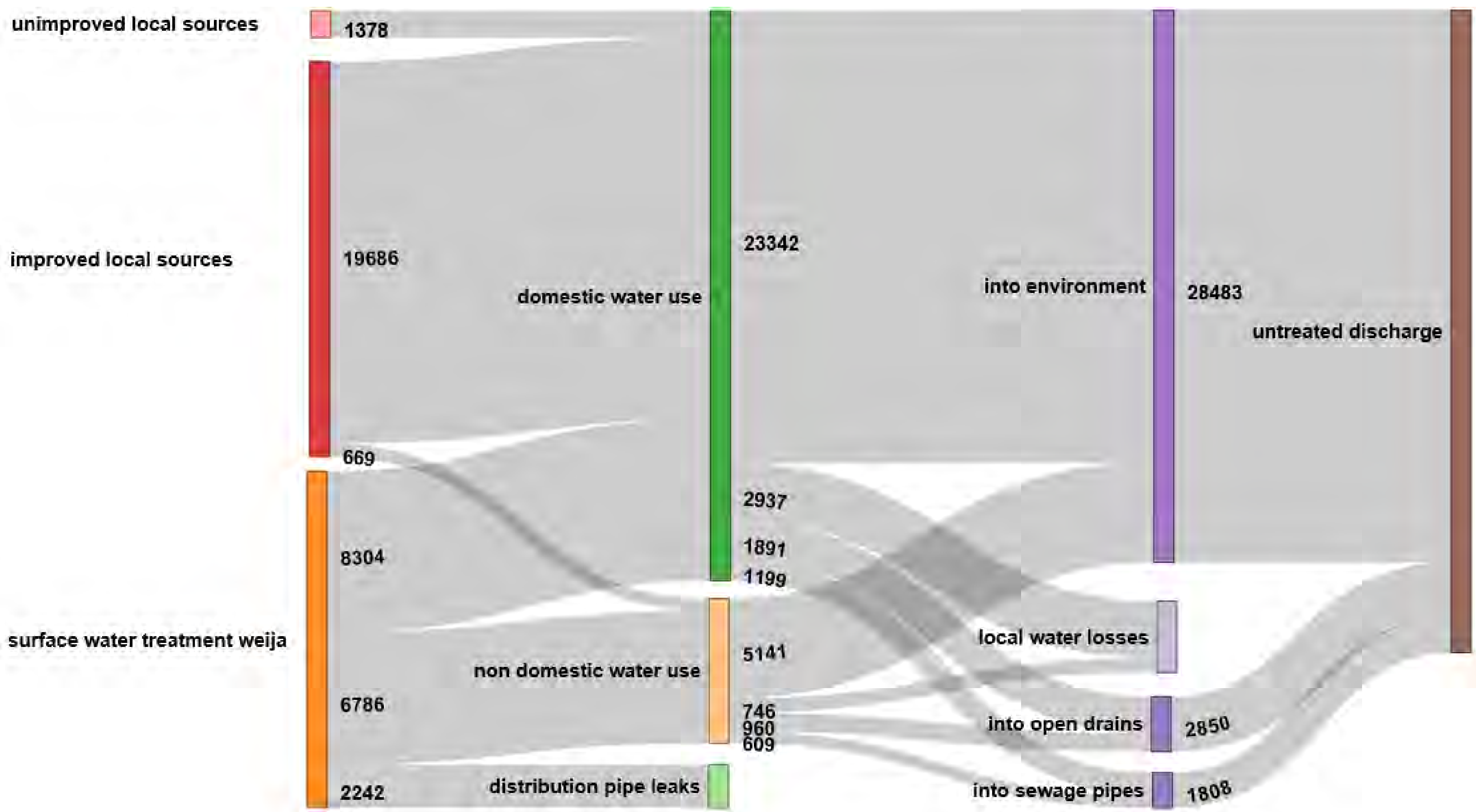
Bar charts with table:



	RECURRENT EXPENDITURE	CAPITAL EXPENDITURE	TOTAL-GHc	US$ Equiv
Solid Waste Management	599,682,168	226,597,031	826,279,199	590,199,428
Excreta Management	3,875,000	232,200,000	236,075,000	168,625,000
Storm Drains & Sullage Conveyance	24,684,000	8,500,000	33,184,000	23,702,857
Healthcare Facility Waste Management	0	2,701,210	2,701,210	1,929,435
Total-GHc	628,241,168	469,998,241	1,098,239,409	784,456,720
US $ Equiv	448,743,691	335,713,029	784,456,720	

Decide on visual presentation

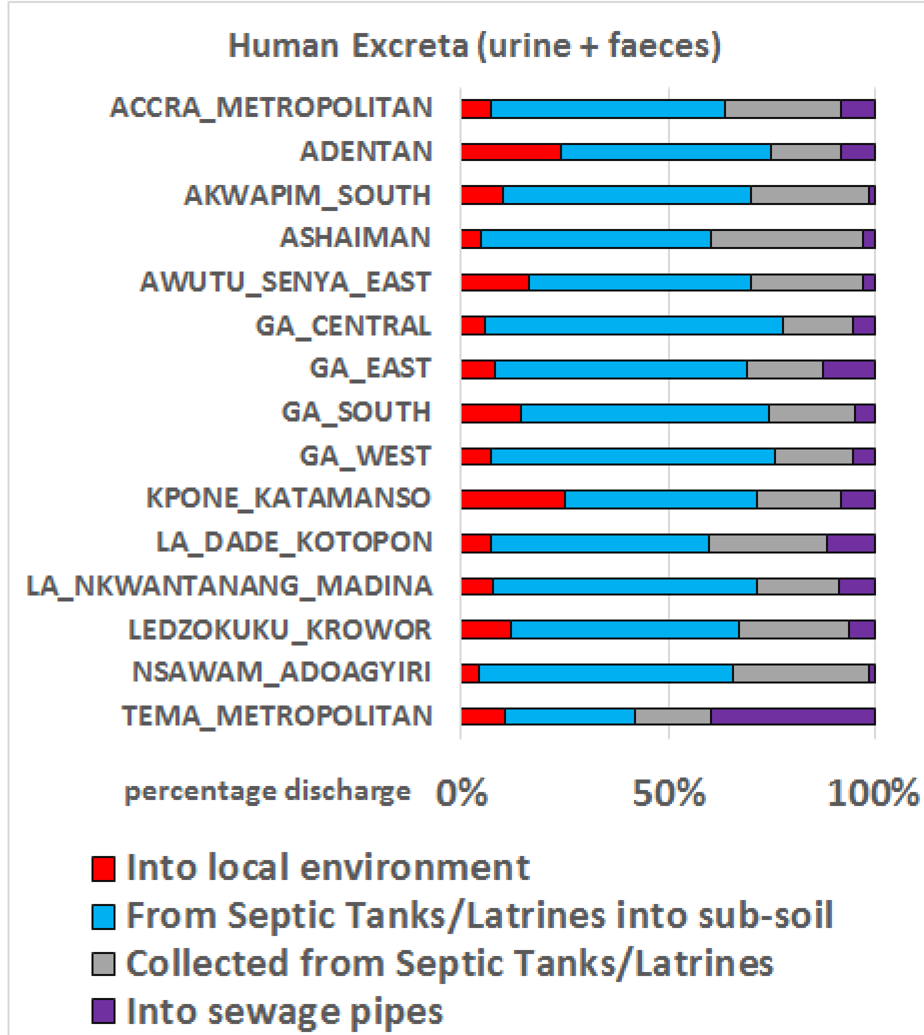
Sankey Diagram of Flows: Example estimates for Ga South 2010 in m^3/day (2012 district boundaries)



Decide on visual presentation

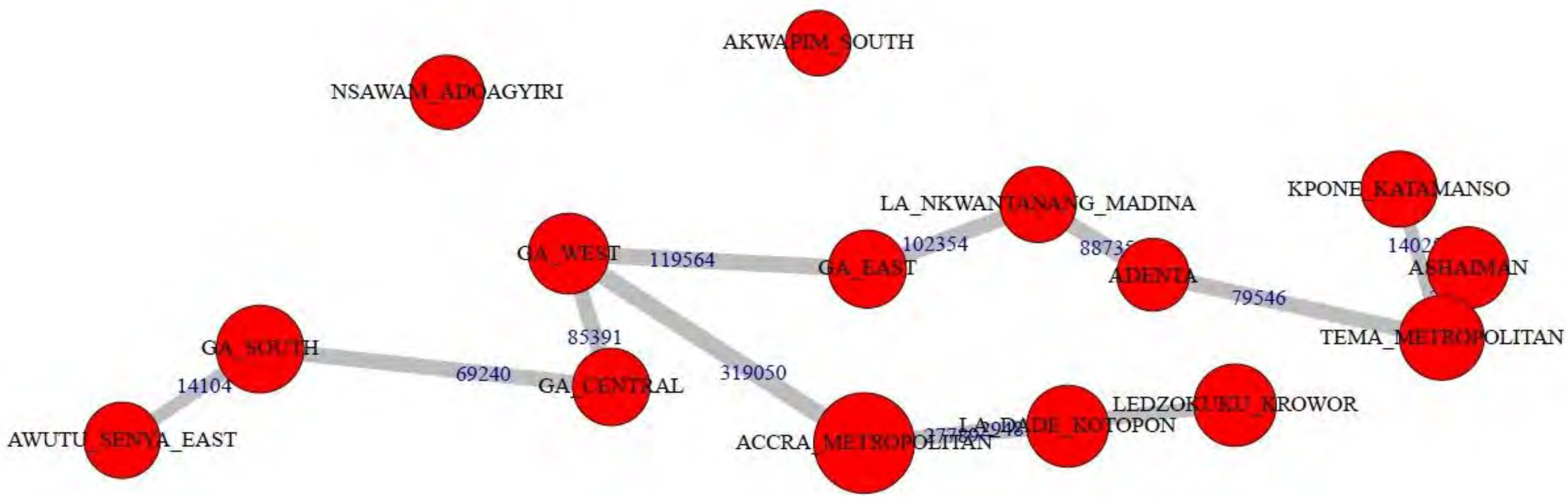
Horizontal stacked bar charts for categories per district

- 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



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Thank you

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