WHEN FLOODS HIT THE ROAD: THE IMPACT OF FLOODING ON URBAN TRANSIT AND ACCESSIBILITY - A CASE STUDY OF KINSHASA, DRC

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Digital Transport For Africa – DT4A – February 15th, 2023

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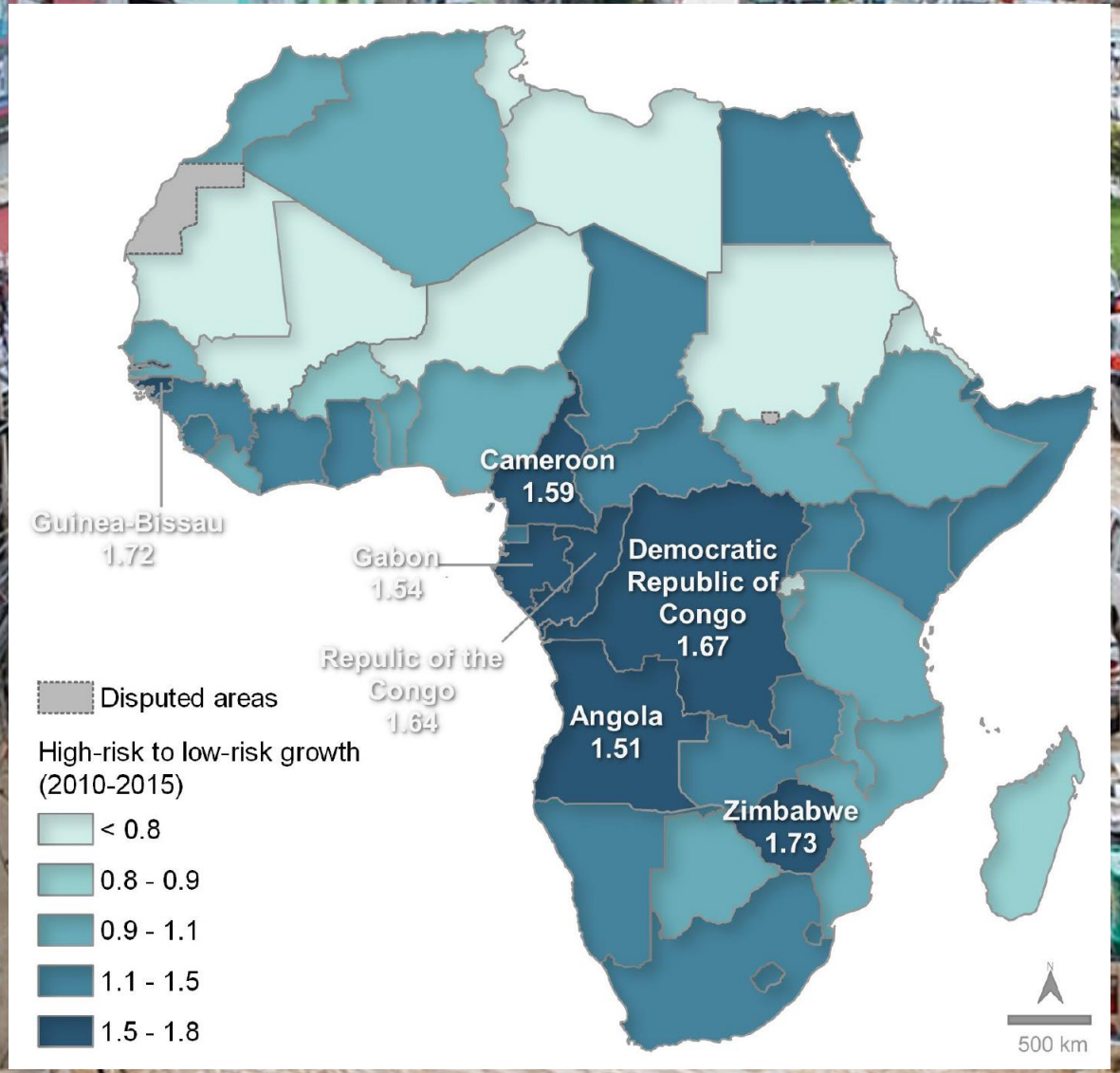


- Urbanization is increasingly happening in flood prone areas: -> increased exposure of people and assets
- Changing climate and weather patterns will potentially increase exposure locally
- Low capacity to mitigate flood consequences, e.g. drainage systems, are insufficient -> increased vulnerability

Deparday, Avner, Rentschler, Gevaert, forthcoming, Understanding the Changes In Africa's Urban Exposure to Flood Hazards

Background and motivation for the study

Accounting for disruptions from natural hazards in Kinshasa – starting with a few questions

Floods occur regularly in Kinshasa (and many other urban areas) - yet little is known about their impacts on transport

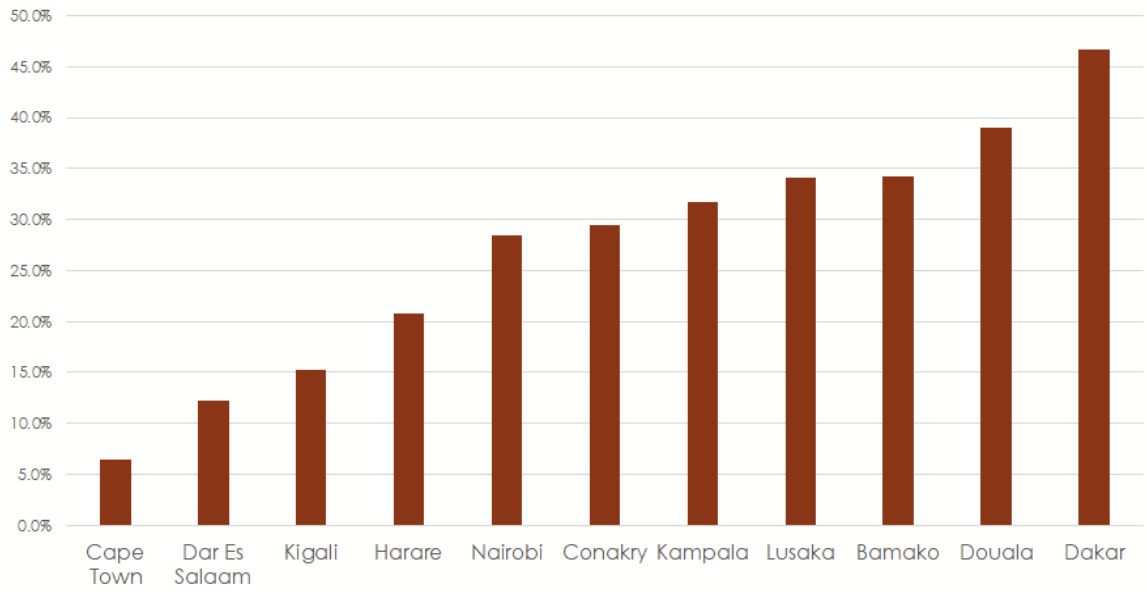
- How do floods impact collective/public travel times, and possibly travel itineraries?
- How do these transport disruptions impact the ability of households to reach their jobs and key services?
- What are the economic costs of such transport disruptions?
- Can analyses help uncover cost mitigation strategies? Including by identifying most critical links that could benefit from public works?

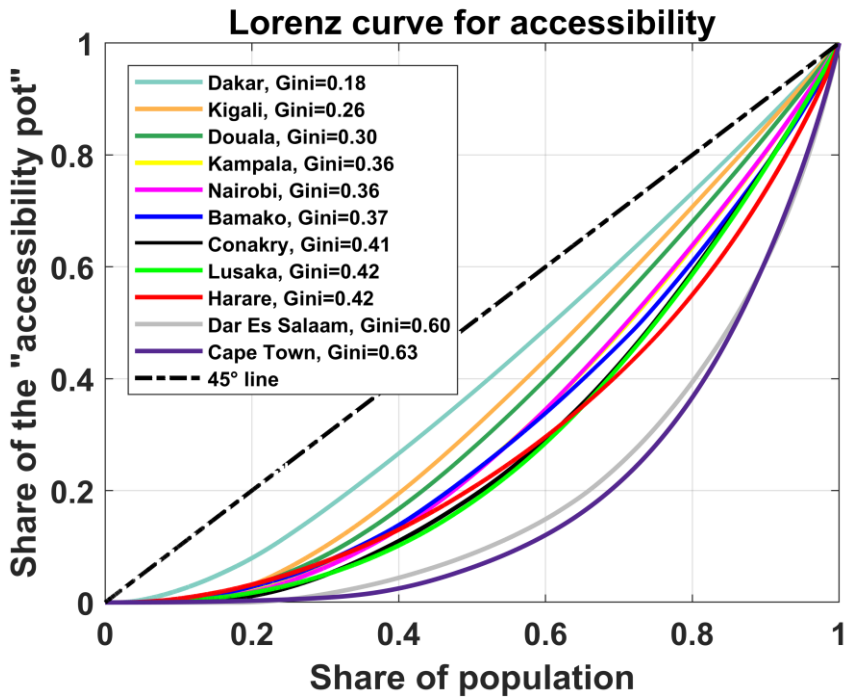
Background and motivation for the proposal

Accounting for disruptions from natural hazards in Kinshasa – where we are starting from

Accessibility studies (to employment or services) are becoming mainstream

- They are now a requirement for World Bank transport projects
- Progress
  - in mapping public/collective transport modes and community road mapping (e.g. OSM)
  - in navigating data scarcity (proxies for jobs,…)
  - in network science computational techniques





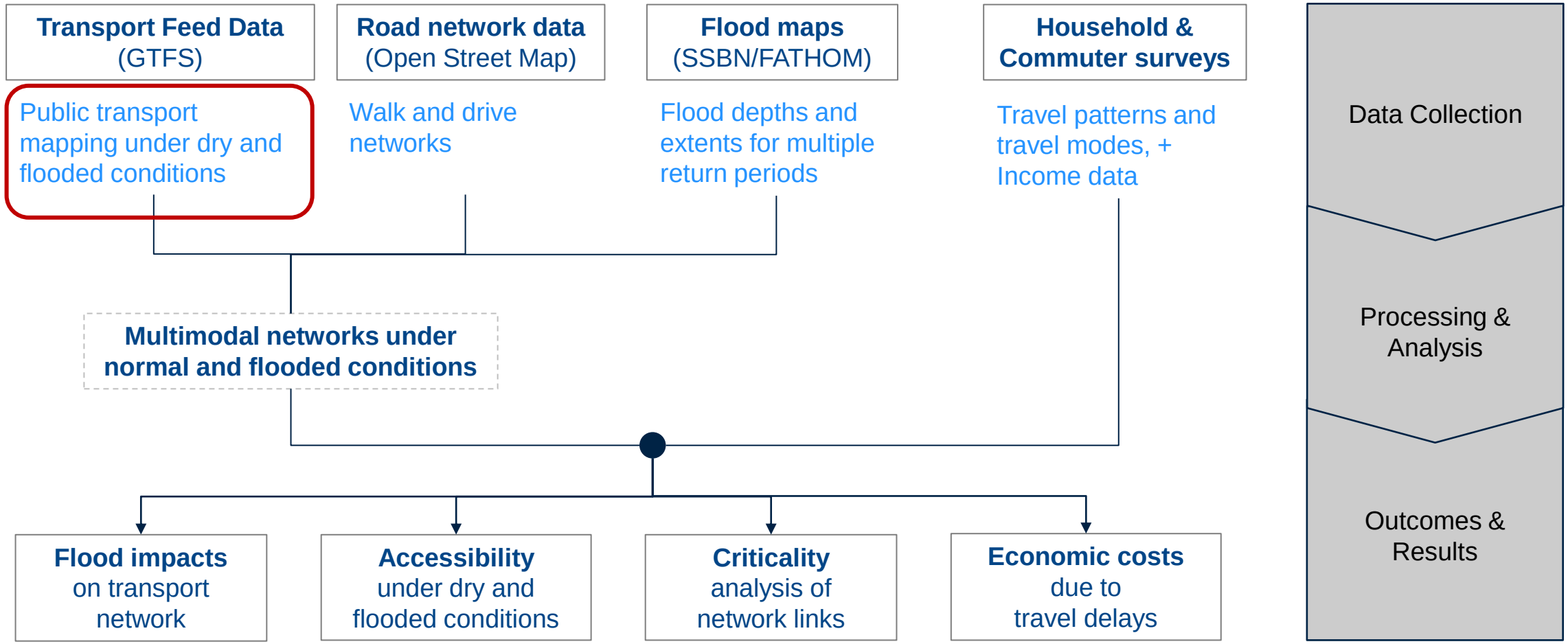
But what is lacking is an understanding of how this accessibility from urban collective transport is impacted by natural hazards

When Floods Hit the Road - Kinshasa

Peralta Quiros, Tatiana, Tamara Kerzhner, and Paolo Avner. 2019. "Exploring Accessibility to Employment Opportunities in African Cities : A First Benchmark." *World Bank Policy Research Working Paper*, no. 8971 (August): 1–42.

Understanding the impacts of transport disruptions – a framework

Overview of the workflow centered on policy and planning relevant outcomes



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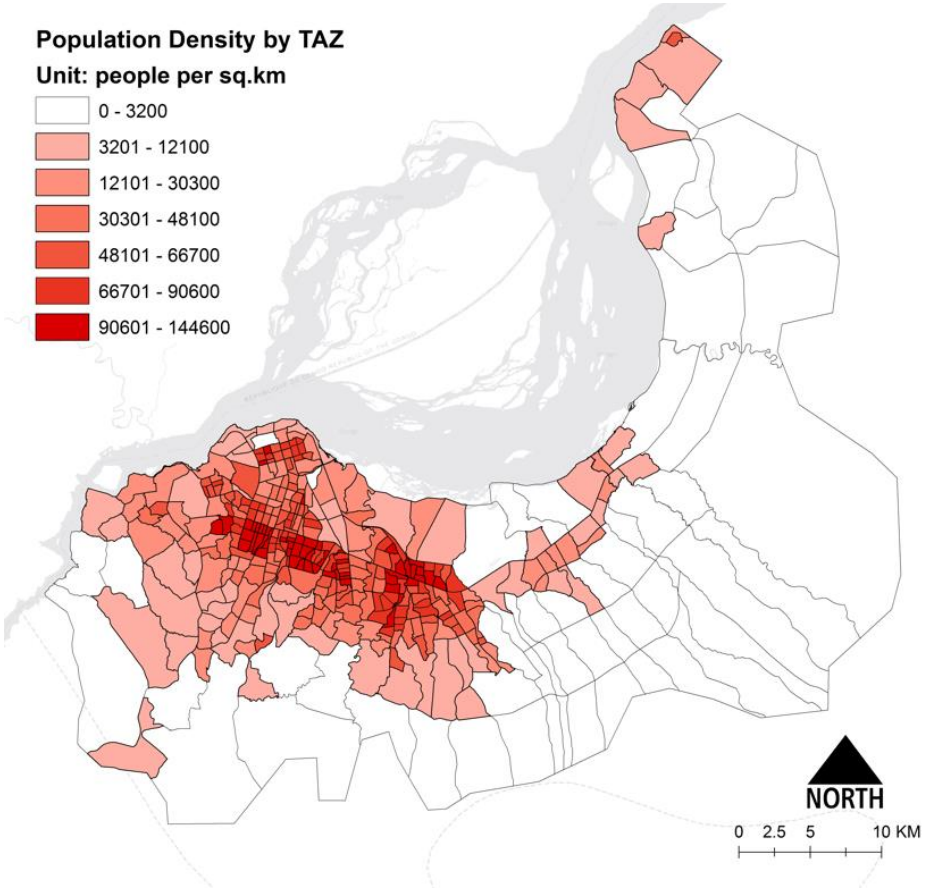
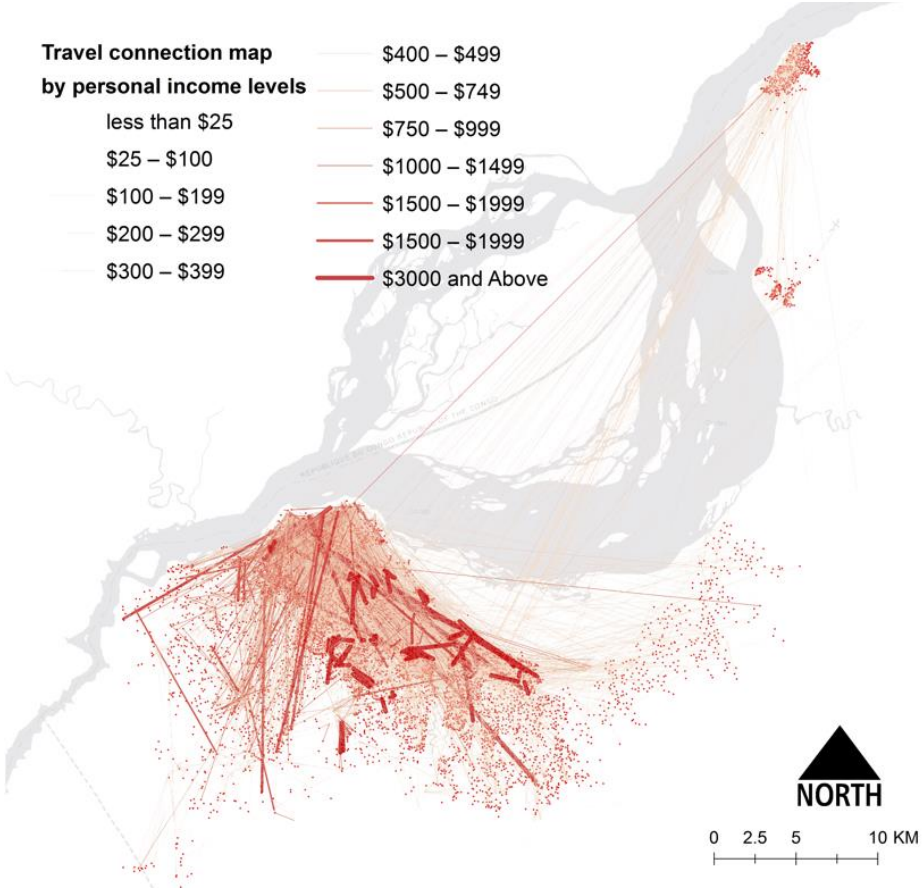
Data 1/3: Commuter survey

Commuter Survey with Origins and Destination, travel modes used and socio-economic status

JICA Commuter Survey (2018) provides information about:

- Origins and Destination for commuting
- Travel mode
- Socio-economic status of the respondent (age, sex, income bracket, purpose of commuting, type of work…)





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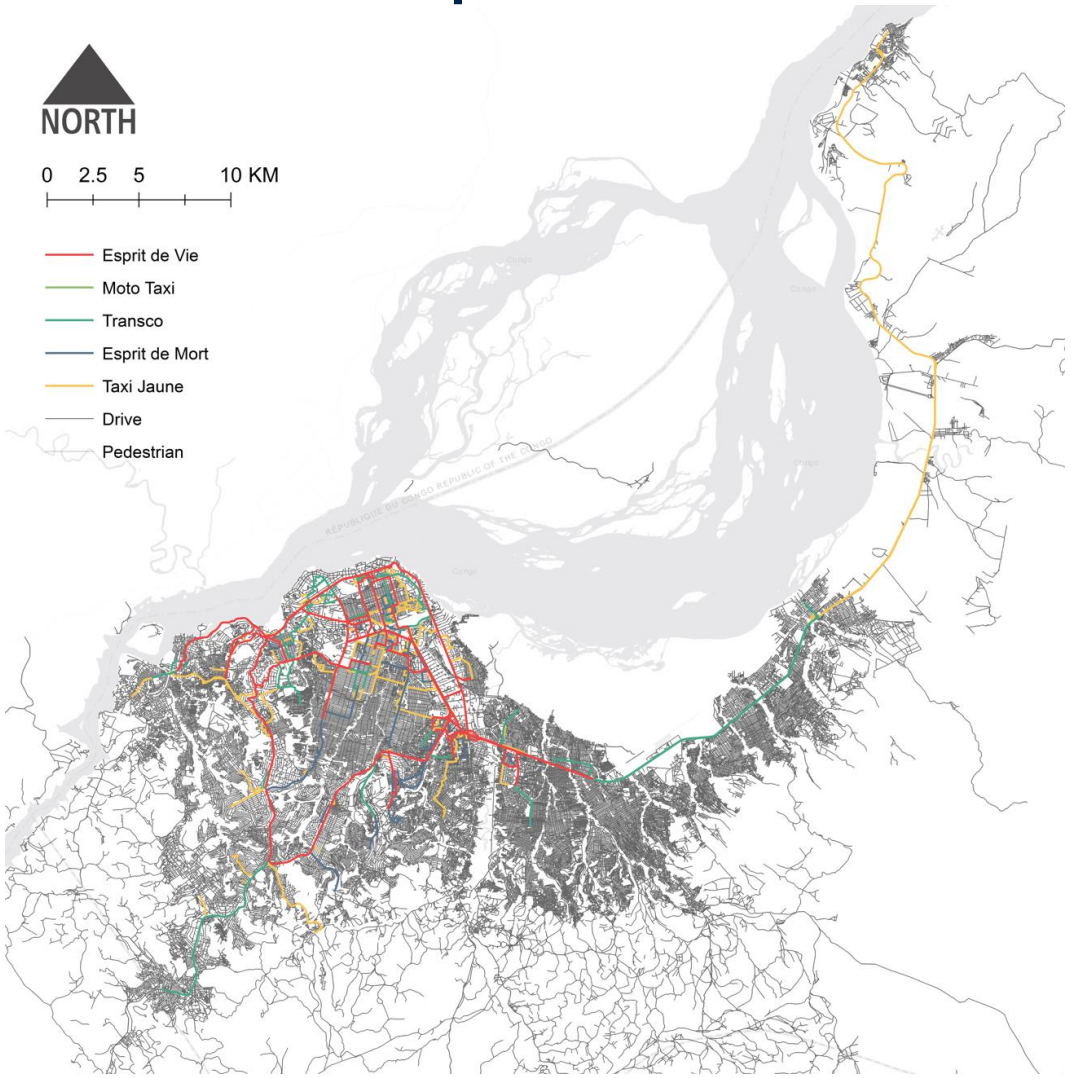
Data 2/3: Transport networks



- OSM for car and pedestrian networks
  - With assumptions for speeds based on the road class
- GTFS feeds for public transport modes
  - Report travel times between stops, can be used to infer speeds
  - Collected under “dry” and “wet” conditions by GoMetro/GoAscendal
  - TRANSCO, Esprit de Vie, Esprit de Mort, Taxi Jaune, Moto-Taxi

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Transco	Esprit de Vie	Esprit de Mort	Taxi Jaune	Moto Taxi
The main public bus service in Kinshasa. In 2020, there are more than 40 bus routes with a total of 986 bus stops (Moovit, 2020).	Minibus taxis with a capacity of up to 22 seats.	Bigger taxis which are usually operated with Mercedes Benz 207 models for inter suburbs trips and long-distance travels within the city.	Cabs painted in yellow with a capacity of four passengers. They usually operate between neighboring suburbs and complete most of the first and last mile services within the city.	Informal moto taxi that provides connection to areas that are enclaved and not easily accessible due the condition of roads and congestion levels. In other instances, trips shorter than three kilometers are done using moto taxi as a first and last mile service.

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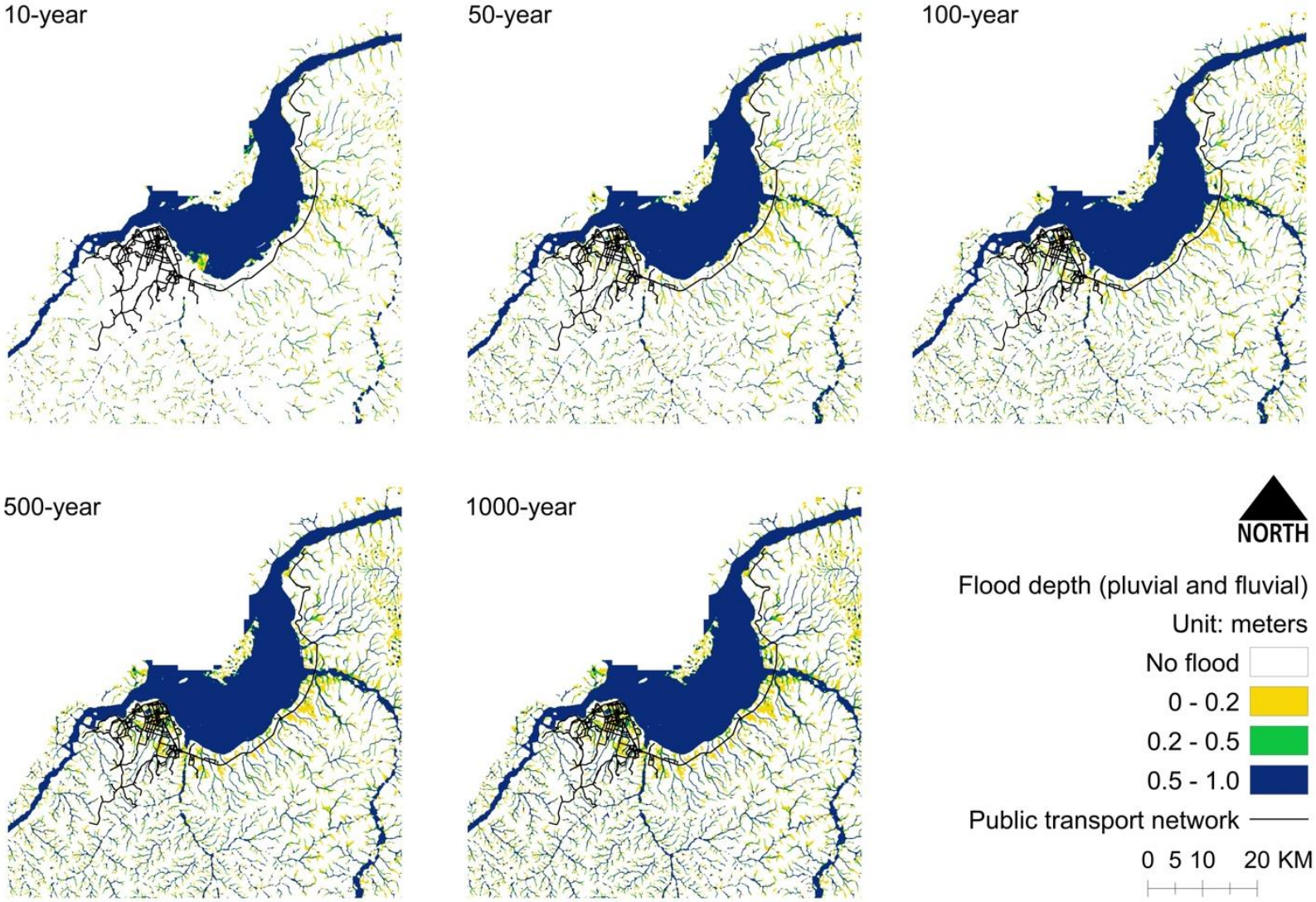
Data 3/3: Flood Maps

FATHOM Global dataset

Use of Global FATHOM maps

- For pluvial and fluvial floods
- 90-meter spatial resolution
- 10 return periods



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Analysis 1: How floods affect the transport networks

Headways and itineraries

3 elements can affect your ability to reach jobs in a timely (normal fashion)

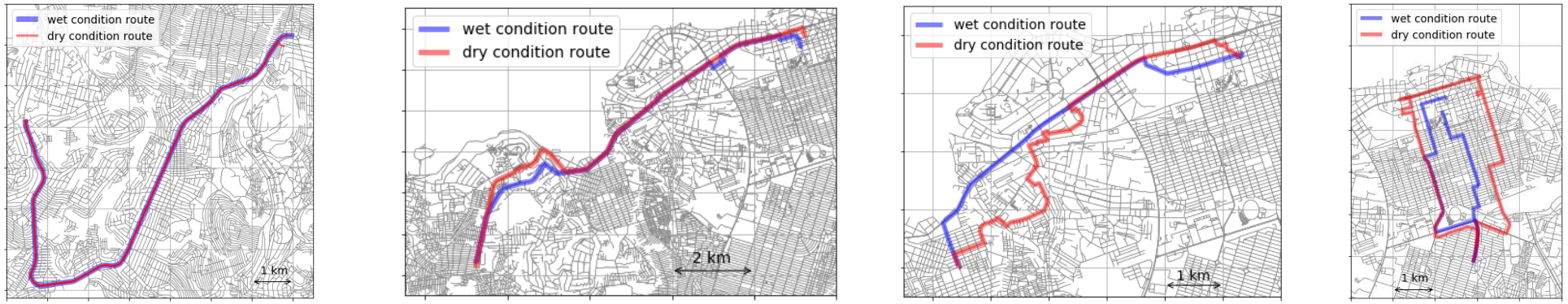
- Frequency of travel services (public transport)
- Travel itineraries: impassable roads, avoided road segments because of possible damage to vehicles
- Travel speeds in wet conditions

Headways/frequencies

- TRANSCO buses don't run under wet conditions

	Esprit de Mort			Esprit de Vie			Taxi Jaune		
	Dry	Wet	Δ	Dry	Wet	Δ	Dry	Wet	Δ
Mean headway (min)	31	44	**13**	34	46	**10**	12	21	**9**

Travel itineraries



- We assume cars and pedestrians cannot travel on roads that experience flood depth > 20 cm (using FATHOM maps)

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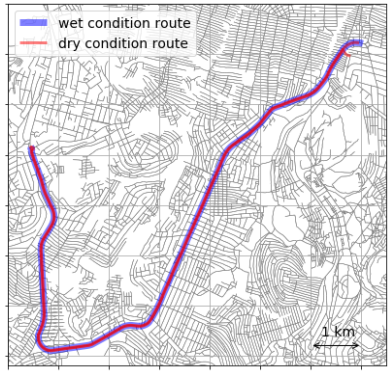
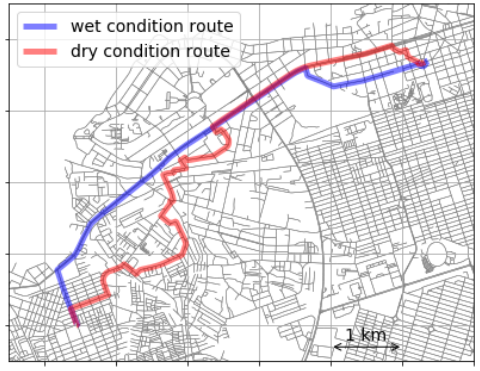
Analysis 1: How floods affect the transport networks (2/2)

Travel speeds

3 elements can affect your ability to reach jobs in a timely (normal fashion)

- Frequency of travel services (public transport)
- Travel itineraries: impassable roads, avoided road segments because of possible damage to vehicles
- Travel speeds in wet conditions





Travel speeds changes in wet conditions are difficult to identify because

- We only have a sample of surveyed routes under wet conditions (28%)
- For many of these routes, the itinerary changes

-> matching procedure to infer travel speed reductions

	Esprit de Mort	Esprit de Vie	Taxi Jaune
	Estimate	Estimate	Estimate
Speed difference [km/h]			
Mean	-3.892	-1.667	-0.574
Median	-3.197	-1.985	-1.573

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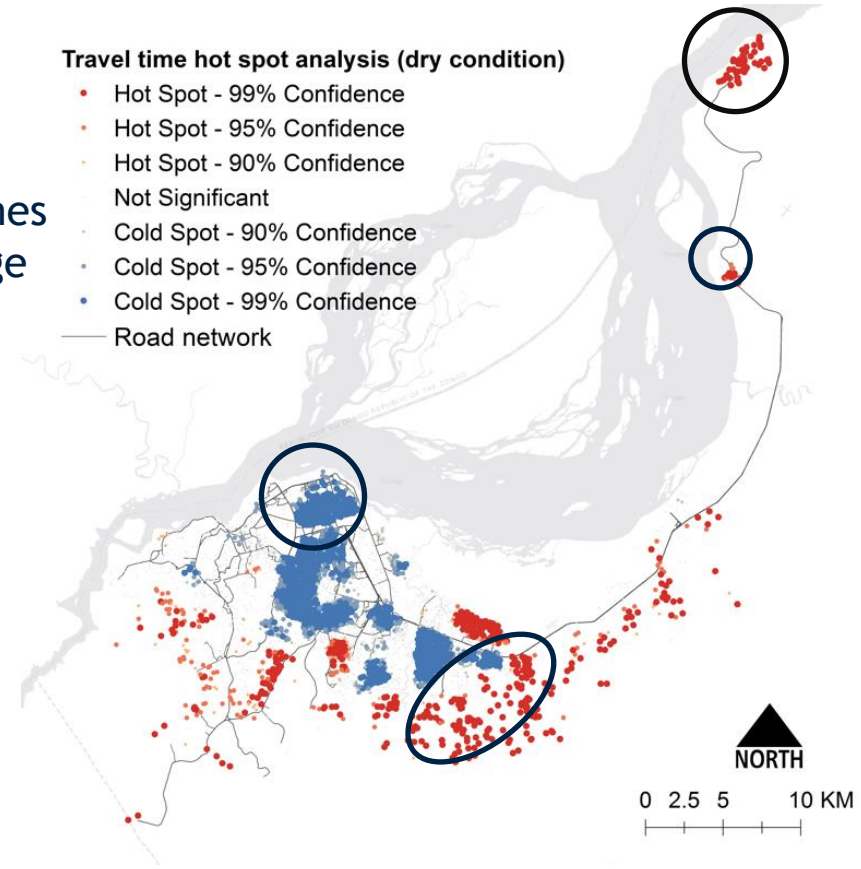
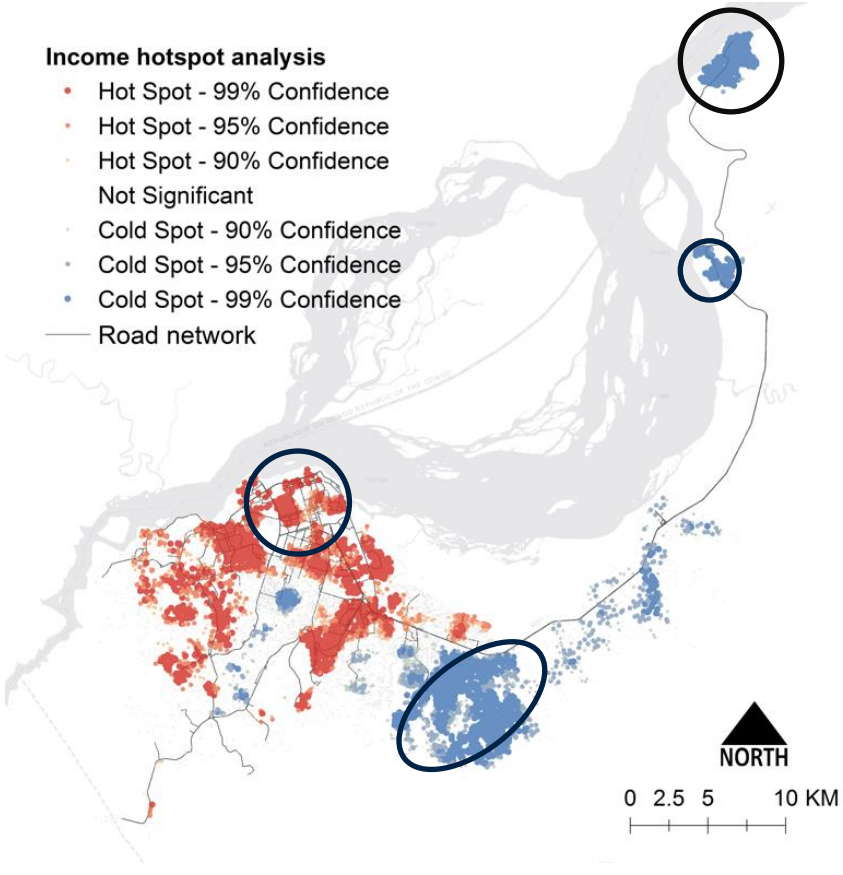
Analysis 2: Accessibility to jobs (1/2)

Travel time and socio-spatial equity issues (under dry conditions)

Hotspot analysis reveals:

- Clusters of high and low commuting times
- Clusters of high and low incomes
- In some instances these diverge





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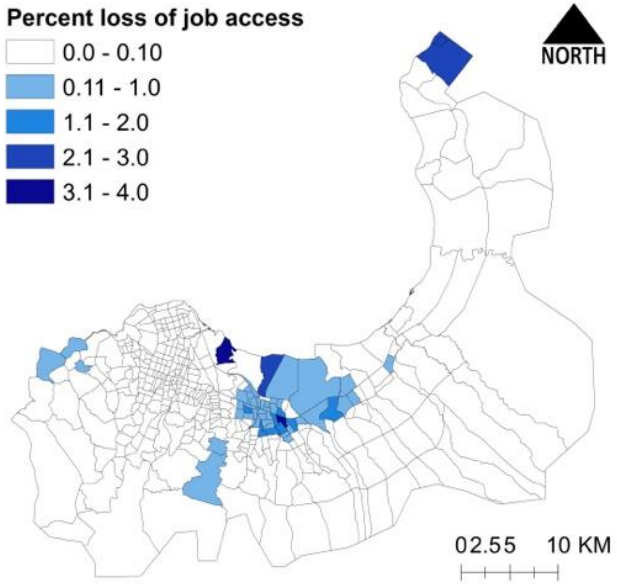
Analysis 2: Accessibility to jobs (2/2)

Travel time delays and accessibility to employment

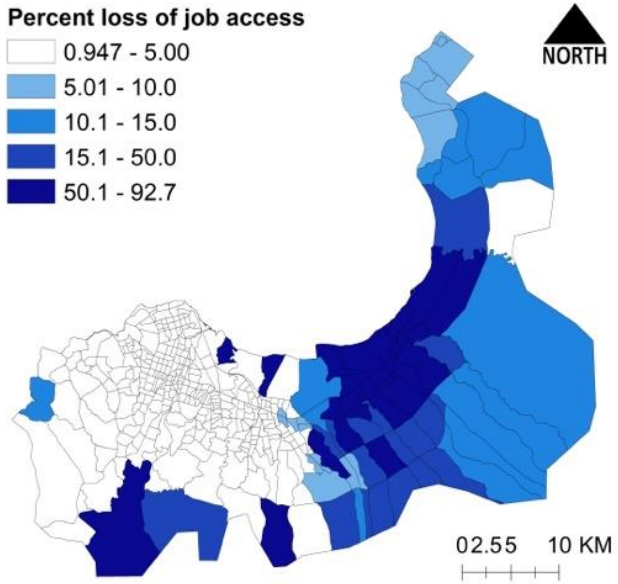
We build the wet network by :

- Removing Transco routes
- Adjusting travel speeds
- Adjusting headways/frequencies
- Removing transport links that are flooded by more than 20 cm

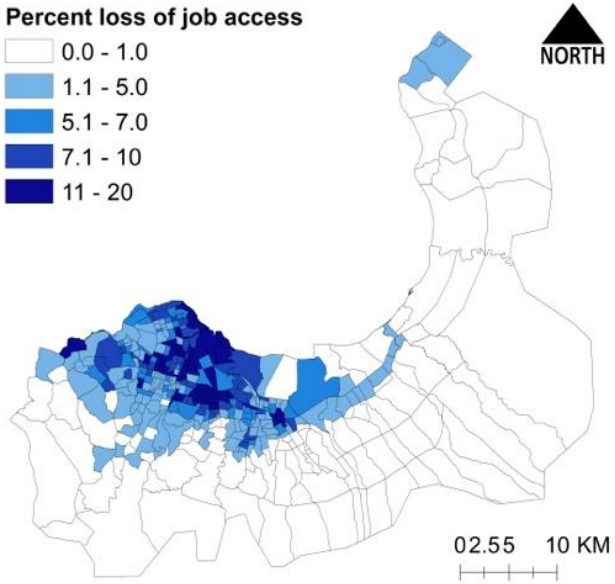
Network Type	Dry Condition Accessibility	Wet Condition Accessibility
Walk	9.1%	8.9%
Drive	84.7%	73.7%
Public Transit (mean waiting time)	20.4%	15.4%



Walking



Drive



Public transport

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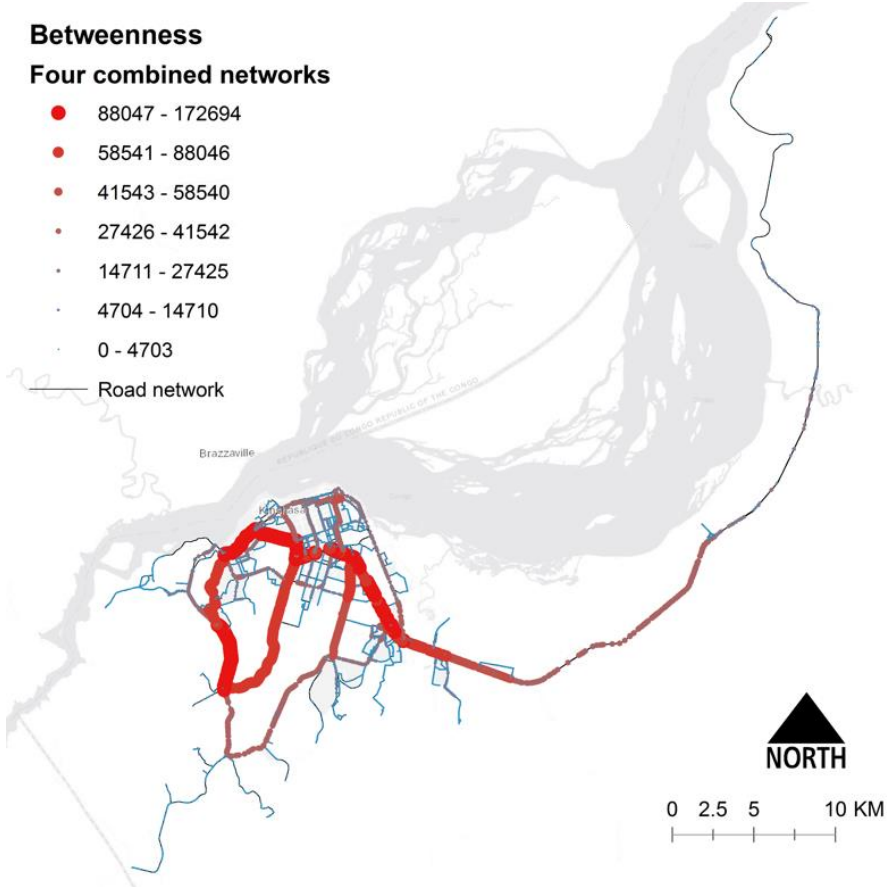
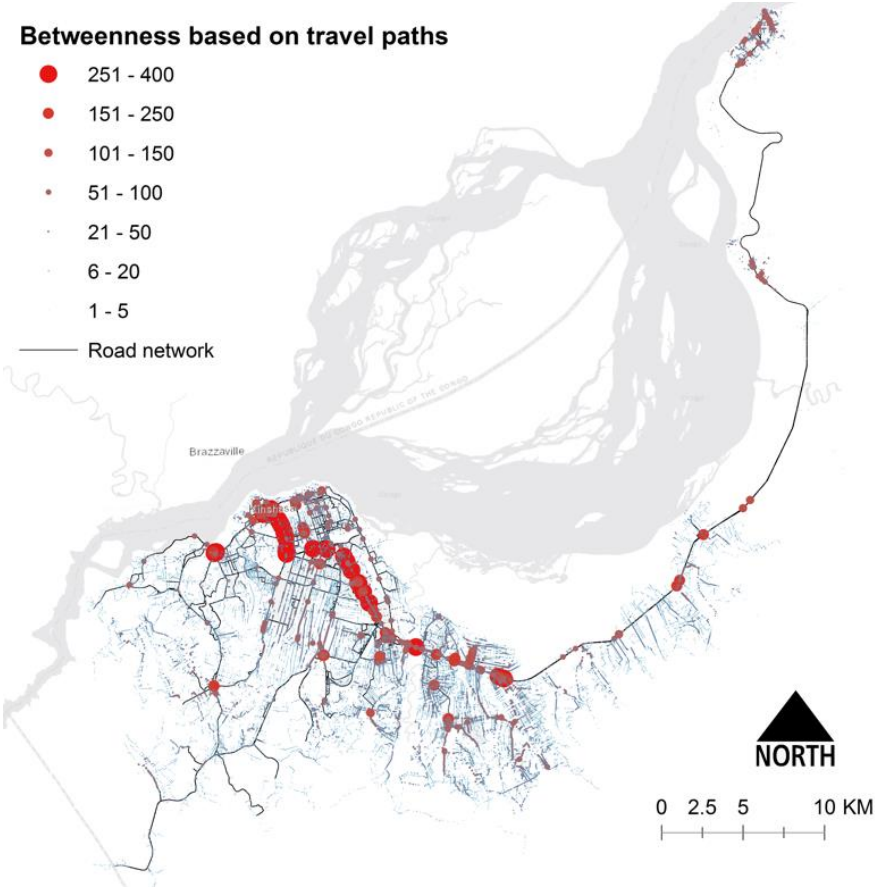
Analysis 3: Criticality

Prioritizing road links for resilience





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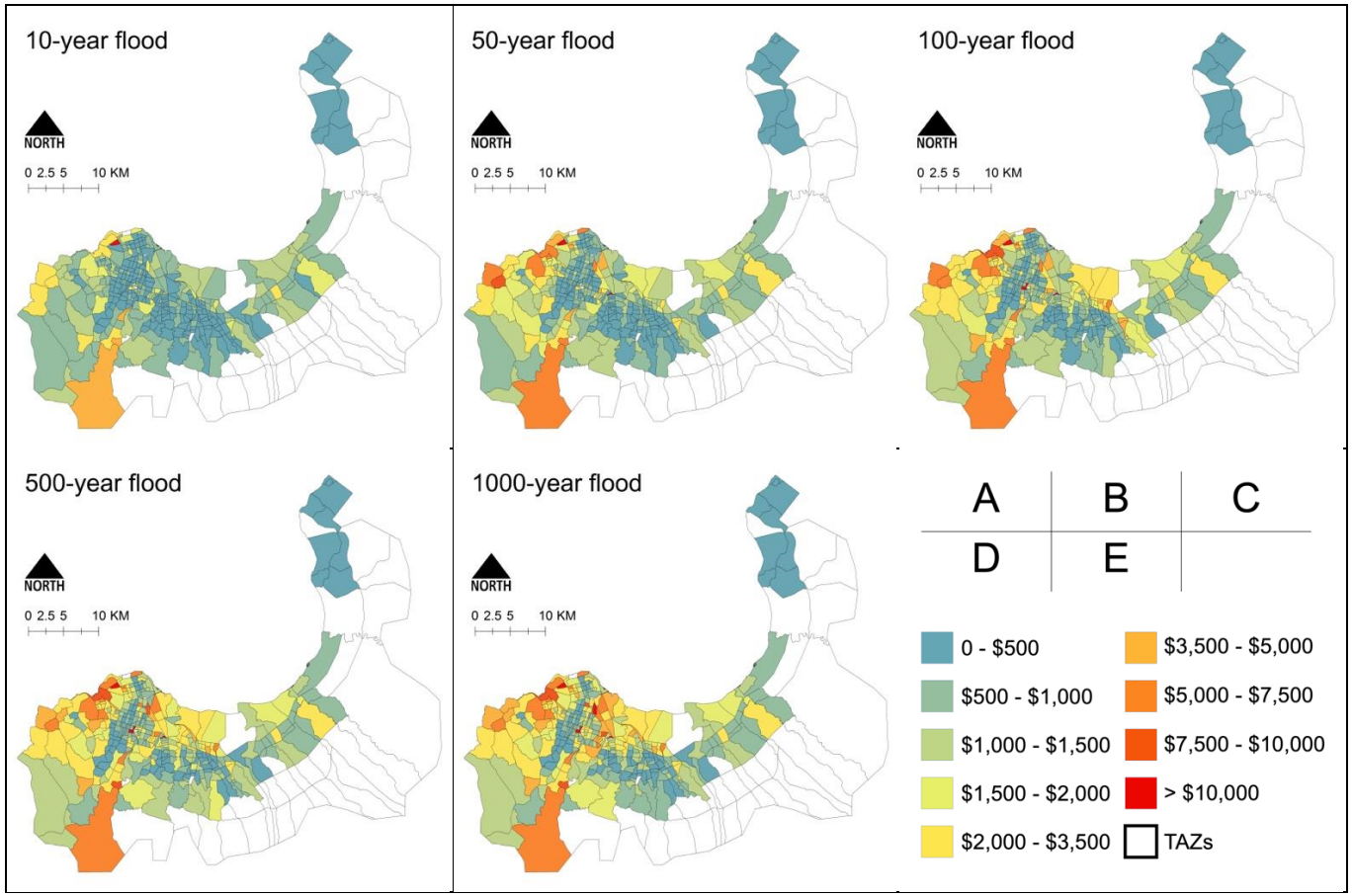
Analysis 4: Economic costs (1/2)

Opportunity costs of time based on income and travel delays



Daily opportunity cost of time ($)	
10 year flood	5,370,000
50 year flood	8,640,000
100 year flood	11,630,000
500 year flood	13,300,000
1000 year flood	14,370,000
Annualized average	1,166,000

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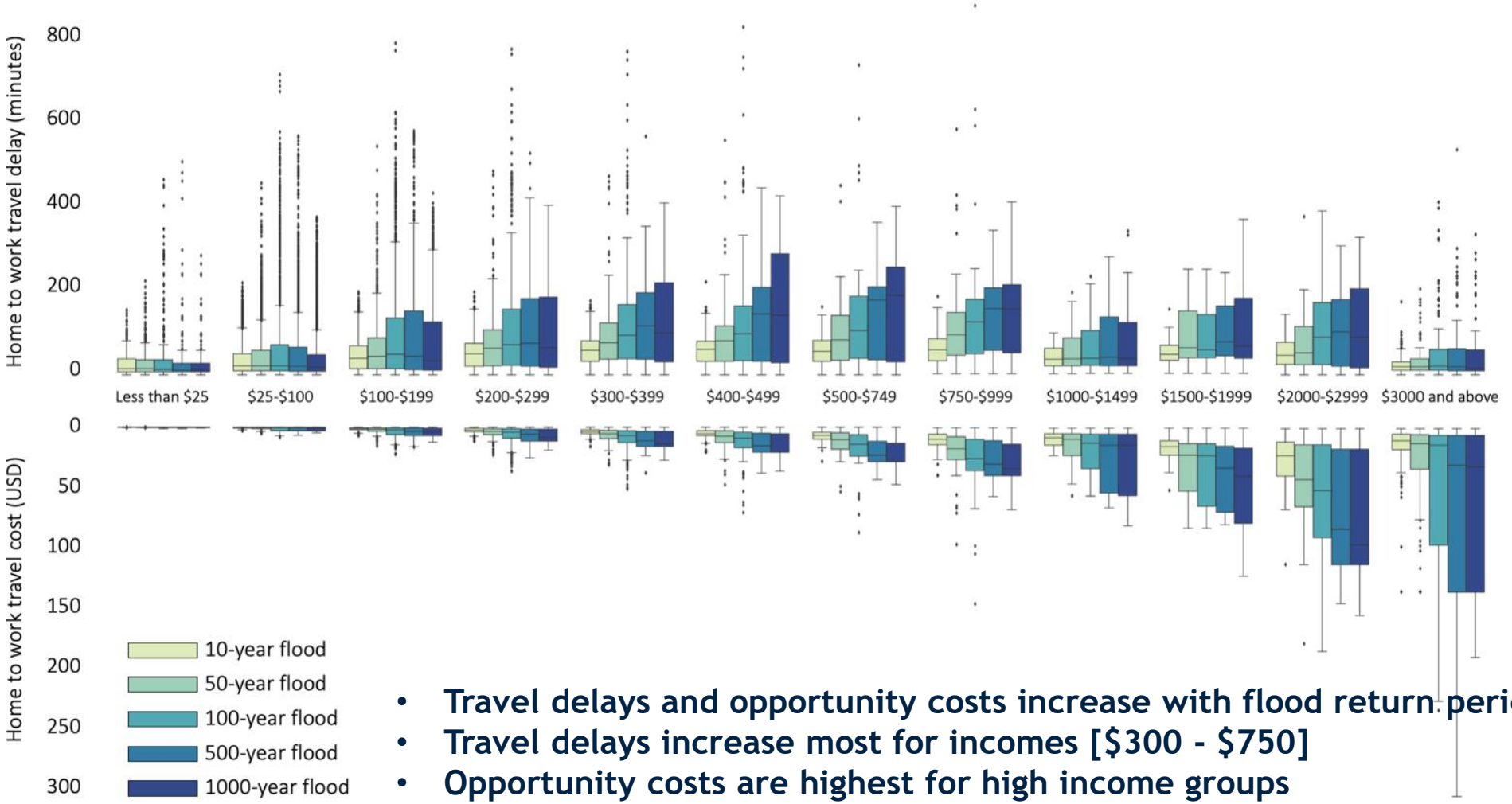
Analysis 4: Economic costs (2/2)

An income disaggregated view of travel delays and opportunity costs



- **Travel delays and opportunity costs increase with flood return periods**
- **Travel delays increase most for incomes [$300 - $750]**
- **Opportunity costs are highest for high income groups**

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Conclusions and takeaways

- The dual condition public transport mapping under dry and wet conditions enables us to get a fine understanding of travel disruptions caused by floods

- Combined with other datasets, this information can be leveraged to shed light on:
  - Loss of employment accessibility from rainy season flood events
  - The most critical transport links in the network
  - Economic costs through commuting delays from floods (one piece of the economic costs of floods)

- Part or all of this study can be replicated elsewhere depending on data availability
  - O/D commuter survey -> travel delays
  - Socio-economic information of respondents -> travel delay costs
  - Location of jobs -> accessibility