Capacity Building for Water Management in Peri-urban Communities, Bangladesh: A Simulation-Gaming Approach

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Supplementary Materials

S1. Game theory models

These are the models used as inputs for game design in the strategy exploration workshop held in peri-urban Khulna. Models 1a and b represent non-cooperative games of current and future drinking water situation respectively. They are modelled as games in extensive form using Gambit (http://www.gambit-project.org/). Fig. 2c is the cooperative game of groundwater monitoring, represented as a game in characteristic function form.

a. Peri-urban drinking water supply game (Current situation)

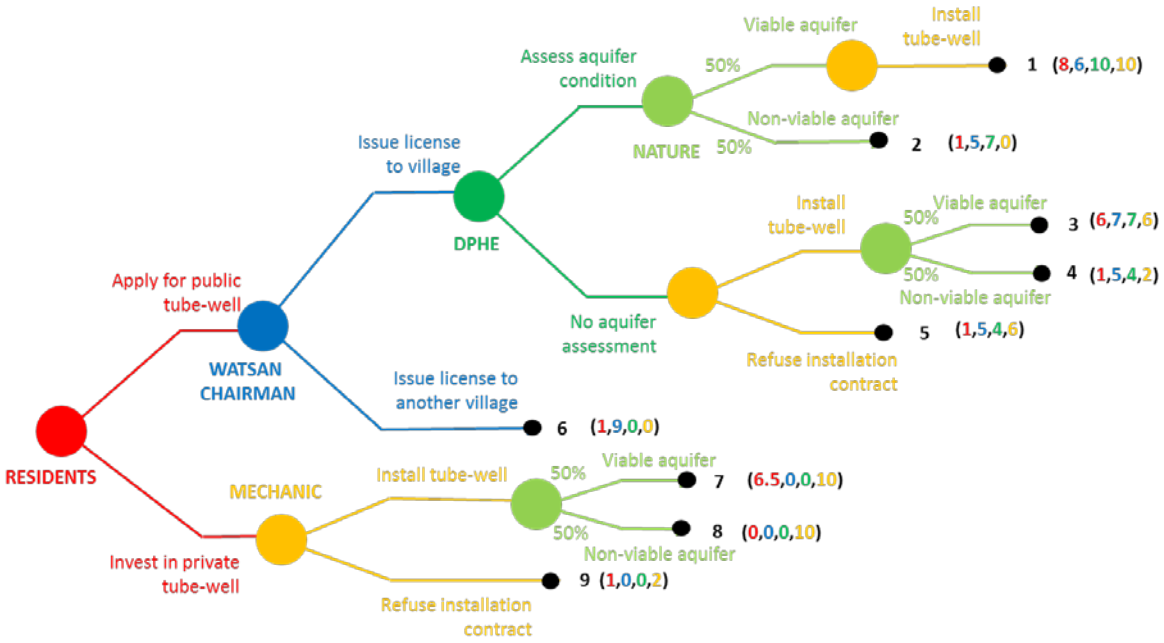


Figure S1. Non-cooperative game theory model of peri-urban drinking water supply.

Table S1. Description of outcomes in the model of peri-urban drinking water supply.

Outcome number	Description
1	Safe, affordable, reliable drinking water supply for village residents via public tube well
2	Return to status quo as public tube well installation in the village is cancelled due to location being non-viable for groundwater abstraction
3	Risk pays off as public tube well with safe, affordable water supply is available in the village

4	Risk does not pay off as the tube-well installation fails. Residents return to status quo
5	No public tube well installed due to unavailability of mechanics. It means a return to status quo for the residents.
6	No public drinking water supply for village residents as licence was not approved. A return to status quo for the village.
7	Risk pays off and residents have access to good quality but costly drinking water supply
8	Risk does not pay off as the result is a failed private tube well installation. Residents return to status quo
9	No private tube well installed due to lack of contractors. A return to status quo for residents.

There are 4 strategic players in this game: Residents, WATSAN chairman, DPHE, and the Mechanic. They are represented as coloured circles in Fig. 1. Their actions are colour coded as the branches of the game tree. Residents are the first player in this game. They have two possible actions: [Apply for public tube-well] or [Invest in private tube-wells]. Based on the action this player selection, the second play in this game is either the WATSAN committee or the Mechanic. There is also one chance player in this game: Nature. Nature has a 50% probability assigned to its two actions in the game [viable aquifer] or [Non-viable aquifer]. In other words, there is a 50% chance that nature will play one of these actions. The combination of actions by players in this game produces an outcome. These outcomes are represented by black end nodes. In total there are 9 possible outcomes in this game (as labelled besides each end node). The description of the different outcomes in this game are provided in Table 1. For example, [Apply for public tube-well] + [Issue license to another village] results in outcome 6. Finally, payoffs in the game are represented in brackets besides each end node. The numbers represents the utility that each player receives from that outcome. These utilizes are also colour coded to each strategic player in the game. The payoffs for outcome 6 are 1 for residents, 9 for WATSAN chairman, and 0 each to DPHE and the Mechanic. A payoff of zero means that the player receives no utility from that outcome.

b. Urban drinking water supply game (Future situation)

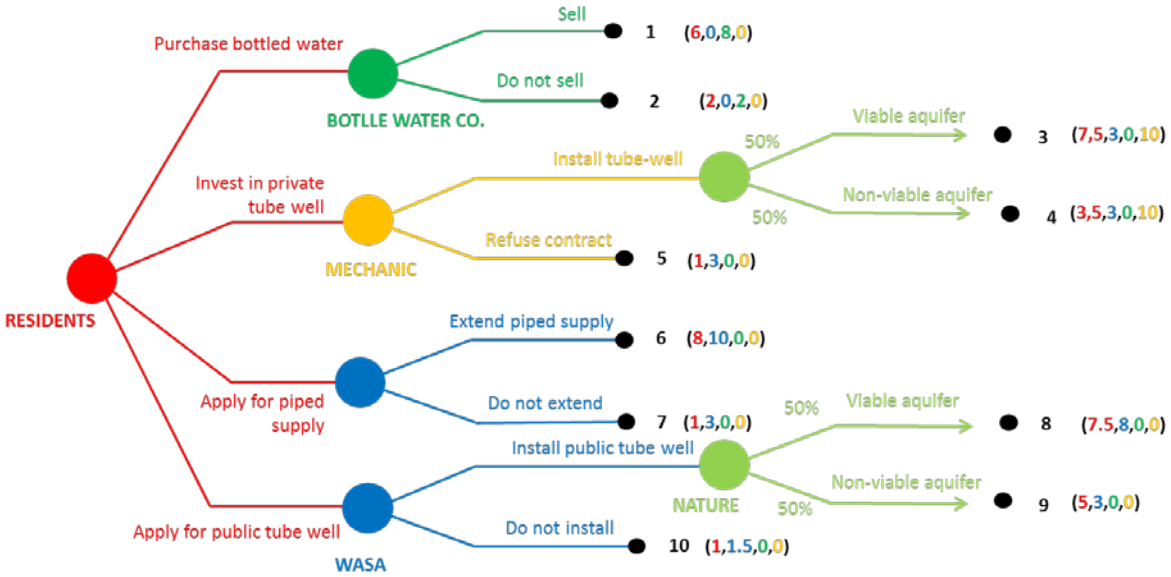


Figure S2. Non-cooperative game theory model of future (urban) drinking water supply.

This model represents the future (urban) drinking water supply situation. There are 4 strategic players in this game: Residents, WASA, the Bottle Water company, and the Mechanic. Nature is the chance player in the game with a 50% probability of selecting [Viable aquifer] or [Non-viable aquifer]. Coloured circles in Fig. 2 indicates the different players and when they move in the game. In this game, residents have 4 actions to choose from. They can [Purchase bottled water], [Invest in private tube well], [apply for piped supply] or [Apply for public tube-well]. They are also the first player in the game. Based on the action selected, one of the remaining 3 strategic players moves next. The combination of actions produces 10 possible outcomes in this game.. For example, [Purchase bottled water] + [Do not sell] results in outcome 2. This outcome gives a payoff of 2 to residents, 0 to WASA, 2 to the Bottled water company, and 0 to Mechanics. Table 2 describes the outcomes in the game. For example, outcome 2 results in a return to the status quo drinking water situation for residents as bottled water companies are unable to provide drinking water supply.

Table S2. Description of outcomes in the non-cooperative model of urban drinking water supply.

Outcome number	Description
1	Costly but convenient, good quality, reliable drinking water supply through informal service providers
2	Return to status quo scenario as bottled water companies are unable to supply drinking water
3	Good quality, reliable, convenient but costly drinking water supply via private tube well for residents
4	Residents incur financial losses due to poor quality and/or unreliable drinking water supply from privately installed tube-well
5	Return to status quo due to unavailability of Mechanics.
6	Good quality, reliable, convenient but costly piped surface water supply for urban residents
7	Return to status quo scenario where urban residents either uses existing DW options or look for alternate options
8	Reliable and affordable groundwater supply with some testing of drinking water quality conducted by WASA. Public tube-wells are shared with other families and requires walking to a central location and/or waiting in line
9	Residents return to status quo as installed public tube-well supplies poor quality and/or unreliable groundwater supply
10	Return to status quo scenario as formal service provider rejects public tube-well application

c. Groundwater quality monitoring game

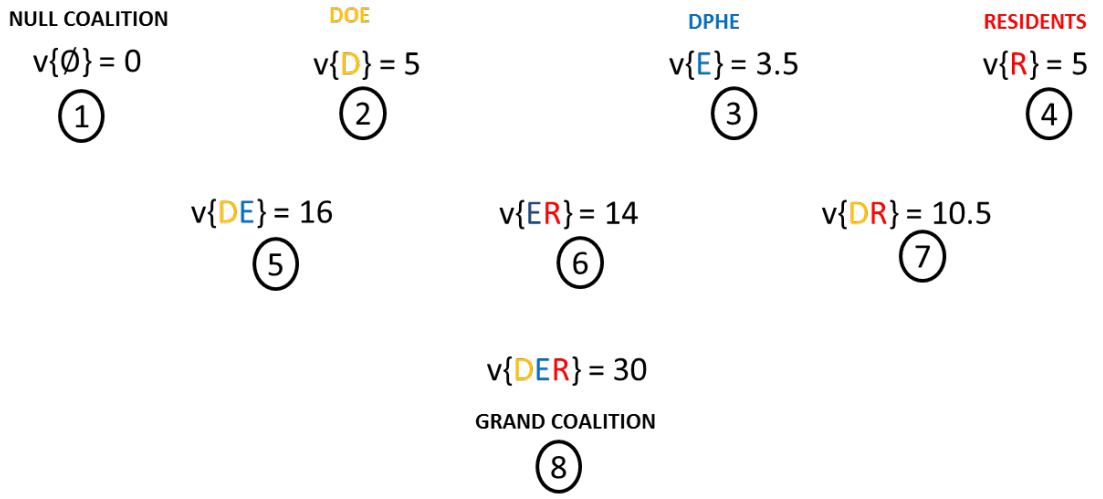


Figure S3. Cooperative game theory model of groundwater monitoring.

The 3 players in this game includes the DOE (D), DPHE (E), and Residents (R). Fig. 3 shows the different possible outcomes, if players monitored groundwater individually or through cooperation. Players can decide to not conduct any groundwater monitoring (null coalition), monitor groundwater individually (D, E, or R), form a coalition with one other player (DE, ER, or DR), or form a grand coalition (DER). This gives us 8 possible outcomes for monitoring groundwater (see Table 3 below). Numbers are also assigned to each of the 8 outcomes in Fig. 3. Each outcome has its own payoff value (v) allocated as a combined payoff, not individually to the players. For example, v{Ø} receives 0 payoffs, while v{DER}, the grand coalition has a payoff of 30, the highest possible payoff possible in the game.

Table S3. Description of outcomes in the cooperative model of groundwater monitoring.

Number	Coalition	Outcome description
1	None	No monitoring of groundwater resources
2	D	Fragmented groundwater monitoring to achieve agency specific objectives
3	E	Minimal groundwater monitoring for drinking water management only
4	R	Basic village -level groundwater monitoring for the purpose of selecting tube well to meet drinking water needs
5	DE	Sector-wide groundwater monitoring via inter-agency coordination. Mostly relates to sharing of resources and data on groundwater conditions (spatially and temporally)
6	ER	Coordinate efforts to survey all local drinking water tube wells. (eg groundwater quality of drinking water tube wells or in public tube wells after installation)
7	DR	Support community-led groundwater monitoring efforts in exchange for sector-specific local GW data. (Eg community uses actor's resources to survey, test local tube wells.)
8	DER	Active monitoring of groundwater across sectors/ geographic regions via coordination between government and water users

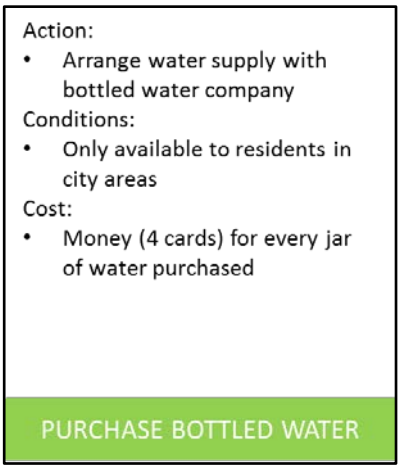
S2. List of abbreviations mentioned in the paper

DOE	Department of Environment
DPHE	Department of Public Health Engineering
JJS	Jagrata Juba Shangha
KCC	Khulna City Corporation
WASA	Water and Sewerage Authority
WATSAN	Water and Sanitation

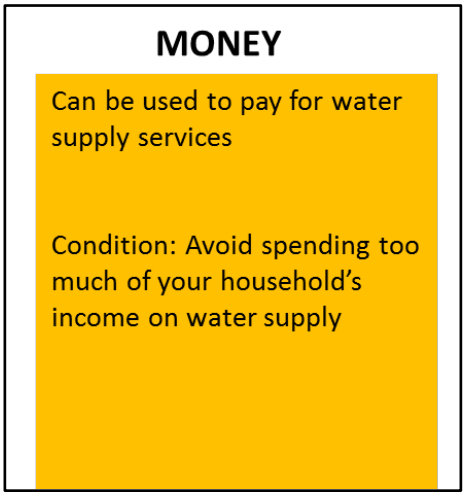
S3. Example game materials used in the role-playing game

a. Role description card for peri-urban residents

b. Action card for residents in session 2 (Left: front, Right: back)



c. Resource card for residents (Left: front, Right: back)



d. Scorecard for residents in session 1

SCORECARD

Place a ✓ under the appropriate face (happy, indifferent or sad) to indicate how well the outcome satisfies your player's values.
Repeat at the end of every round.

PLAYER: Village residents	**SESSION 1** **(PERI-URBAN WATER SUPPLY)**								
	ROUND 1			ROUND 2			ROUND 3		
SATISFACTION ➡ VALUES ⬇									
Safe drinking water (quality)									
Reliable water supply (availability)									
Affordable water supply (cost)									
Convenience of water supply (eg distance, time, effort)									
Availability of alternatives									
Other _____									