Ruling Big Data Use in Urban Flood Risk Mitigation

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This article explores the link between jointly agreed rules and the use of 'big data' in the action arena sustainably managing flood hazards in the Denver Metropolitan Area (U.S. State of Colorado) since 1969 – a case that has attracted attention in the past being frequently used as a model to develop similar action arenas in urban areas worldwide. The analysis focuses in particular on the influence of financial reporting rules on the use of 'big data' to inform capital investment decisions in the months after the catastrophic 2013 Colorado flood which highlighted the weaknesses of the existing drainage system.

Keywords: Big data, institutional analysis, flood risk management

1   Introduction

The expansion of settlements places pressure on draining systems protecting urban inhabitants and businesses from changing weather patterns. In light of this development, public, private, voluntary, and other types of actors from multiple administrative levels and issue domains sharing an interest in managing these facilities search for reliable information to identify and prioritize developmental needs (Stead, 2014; Huntjens et al., 2012). In this context, the development of various methodologies and technologies began; to organize insights from multiple sources within one high volume, high velocity, high variety and easily accessible information asset (Heidrich et al., 2013) - also defined as 'big data' (Gandomi and Haider, 2015; Özköse et al., 2015).

This empirical setting in this context is defined as an action arena that includes a set of bounded-rational actors with different levels of authority that can only gain a relatively comprehensive understanding of the available actions and the costs and benefits of potential outcomes when using the information provided by others (Ostrom and Crawford, 2005: 189). Several studies observed that rules influence which information actors use (Ingold, 2014; Heidrich et al., 2013; Satterthwaite, 2013). Here, findings vary with the setting created by these rules, as this and related research has shown. A small and homogenous group of actors with shared preferences is more likely to engage in direct and constructive deliberation than a large and diverse group (Poteete and Ostrom, 2004). In large settings, information is hardly directly accessible (Fleischman et al., 2014, 15). Actors depend on other actors to share their information (Berkes, 2009), but not

all potential sources of information are granted entry, or are recognized as such, nor is information equally weighted (Martens van Weelden, 2014). Rules determine what information can be considered as reliable (Ostrom and Crawford, 2005). Agrawal (2014) observes that in particular rules facilitating reciprocal communication and the building of trust increase the potential that actors use the information of others.

The here presented research complements the available evidence. It is the first to systematically identify the individual working parts of rules, and to explore their influence on the use of 'big data' in the action arena sustainably managing flood hazards in the Denver Metropolitan Area - a case that is frequently used as a model to develop similar action arenas in urban areas worldwide.

2 Ruling Big Data Use in Action Arena Managing Denver's Flood Risk

Previous research highlighted that after observing substantial information gaps in the action arena managing flood hazards in the Denver Metropolitan Area, local decisionmakers and engineers took on the challenge to develop rules to help them address these shortcomings. Their efforts resulted in a statute in 1969, which created a multicounty special district exclusively for flood hazard mitigation (Grigg, 2011b). The Urban Drainage and Flood Control District ("the District" hereafter) is an independent agency with the mandate to enhance the capacity of local communities to access information about the risk to persons and property from flood hazards inherent in the Denver Metropolitan area as a whole, and to adapt their efforts to coordinate, plan, construct, and maintain drainage and flood control infrastructures within the region. It consists only of a small number of staff as well as engineering contractors and is governed by a Board of Directors ("the Board" hereafter); members of which are appointed to represent their community (e.g. City and County of Denver). This structure has already been defined as a positive example of sustainable stormwater governance in Handmer (1990) and Grigg (2011a, 2012).

The District has recently become more visible to the general public, particularly as an information broker in the aftermath of the 2013 Colorado flood. Central to its operation is an online, open access database that encompasses not only all the hydrology, hydraulic and drainage master planning studies for areas in the region, but also meeting minutes providing detailed information of the decision process as well as the decisions (available via http://udfcd.gisworkshop.com). This asset incorporates information collected, interpreted and disseminated by local decisionmakers and engineers that share notions of validity but also professional competence in the area of urban flood hazard mitigation and whose expertise is recognized in the action arena. The development of this asset is facilitated by three volumes of the Urban Storm Drainage Criteria Manual, prepared and agreed on by the District in collaboration with groups of experts in various aspects of

stormwater management and at levels of government. In addition to the afore-mentioned documents, the District's budget and the Board's meeting minutes are uploaded, as is the more informal newsletter in which the District's leadership directly addresses residents and businesses in the Denver Metropolitan Area. It is a set-up designed to support the District's ambition to help local decisionmakers and engineers to jointly address multi-jurisdictional drainage and flood-control problems in the region. Part of this is not only the maintenance of the existing draining system but also the coordination of funds to design and construct new facilities where needed in the region.

Prior case studies indicate that skillful leadership and its structure have facilitated establishing the District as an agent facilitating the use of information within the action arena in this context (Handmer, 1990; Grigg, 2012). The here presented discussion introduces an analysis complementing this literature. It investigates the causal link between the independent variable ‚rules' and the dependent variable ‚use of 'big data''. More specifically, it focuses on the influence of financial reporting rules on the use of 'big data' to inform capital investment decisions in the months after the catastrophic 2013 Colorado flood that highlighted weakness in the existing drainage system.

3   Data Collection

The data was collected and analyzed between September 2014 and January 2015, starting with an open-ended interview with David Bennetts, leader of the District's Design Construction Maintenance program. The one-hour interview was conducted in their headquarters on September the 22nd, 2014. The data from this interview was used to outline the case settings and verify research findings.

In a second step, two independent coders identified and analyzed the content of the rules that -according to the District's 2013 Comprehensive Annual Finance Reports ("CAFR" hereafter)- were significant for structuring the action arena deciding on a budget and the subsequent five-year plan for capital investments („CIP" hereafter) following the 2013 flood (UDFCD 2014a). The research in this context employs a coding scheme specifically developed to reliably define the working parts of rules structuring action arenas and how these change over time, whose components shall be presented below (Siddiki et al., 2011, Crawford and Ostrom, 2005):

Attribute (A): the animate agent that is to carry out a particular action
Object (B):   the receiver of the aIm
Deontic (D):   the prescriptive operator specifying if an action is required, forbidden or permitted a(I)m: the action itself
Condition (C): the boundaries in which the required action has to be performed
Or else (O):   the sanctions associated with the non-compliance of a prescribed action.

Following Siddiki et al. (2011), depending on which configuration of those working parts a rule is composed of, it was classified as a strategy (ABIC), a norm (ABDIC) or a principal rule (ABDI-CO). While the latter gives actors in an action arena a clear incentive to obey, actors are more likely to ignore a strategy or norm (Ostrom 2005a: 16-18). Furthermore, seven types of rules are distinguished in this context, using the aIm as an indicator: rules that regulate who can enter and leave an action situation are defined as boundary rules. Position rules, in contrast, state whether there is a defined number of actors in specific positions in an action situation. Other rules influence the costs and benefits that actors assign to a particular action (payoff rules), the scope of this action (scope rules), and the way it is monitored (information rules). Aggregation rules determine 'who is to decide' which action or set of activities is to be undertaken. Choice rules specify what actors in specific positions must, must not, or may do at a particular point in a decision process in light of conditions that have, or have not, been met at that point of the process (Crawford and Ostrom, 2005).

Finally, the same two coders analyzed the use of ‚big data' in this action arena. This third step of the analysis focused on the activities recorded in publicly available records of monthly Board meetings (UDFCD 2014b). It includes only activities emphasizing communication and deliberation in relation to planning and deciding the budget and the subsequent five-year plan for capital invest-ments in the months after the 2013 flood.

3.1 Results

The ABDICO-based analysis suggests that "the District" was the most represented Attribute in the set of rules outlined in the 2013 CAFR, followed by "the Board", "other participating local entities" and the District employees". Table 1 presents all the rules that assign each of these Attributes to one or more positions within the action arena (position Rules). While P3 statements specify that the Board is the governing body of the District, P1 statements assign the District as the administrative entity. P2 statements outline the statutory functions, which they must observe (e.g. planner, operator). It is stated in this context that the District coordinates plans to minimize the risk to persons and property from flood hazards inherent in the area. While these rules define the number of actors in specific positions, other rules define the action that actors in this position can take. These rules are distinguished from each other based on the aIm component by Crawford and Ostrom (2005); Ostrom (2005c).

The information rules shown in Table 1 have the aIms "report" and "record" or similar words implying that information is used or distributed in common. The District is expected to account for, estimate current, and forecast future expen-

ditures and revenues (I1). The District is accountable to the Board, project partners, taxpayers, and the State of Colorado. It has to prepare a budget and present it at a public hearing and to the Board (I2).

Aggregation rules determine the responsibility for accounts receivable (A1), account payable (A2), the budget for the year ahead (A3), and setting the mill levy (A4). These statements included the aIm "responsible". Much less frequently used verbs were "manage", "modify" and "amend". This highlights an equal partnership between the district and associated local authorities, and that the District is accountable to the Board.

Where the aIm indicated an action, such as "use, include, maintain, construct" the statement was coded a choice rule. These statements suggest an order in which funds are appropriated (C1), when they can be appropriated (C2) and how to manage funds that are not appropriated (C3).

Statements containing the aIm "pay" and including "share" were coded as payoff rules; clarifying who gives and receives payoffs. These statements detail the District's liability towards its partners (Y2), and staff (Y3). Y1 indicates statements that outline resources such as the property tax (mill levy), which actors, other than the District, have to contribute, In this context, it is clarified that the District's financial participation in the construction of drainage facilities, which will be owned by other local governmental entities, covers at the maximum 50 percent of the costs. The rest is shared between local sponsors. Statements related to joint funding imply that the District and the local governments have agreed on a plan outlining the costs and benefits of joined projects. These costs need to be reflected in the budget, regularly reported, and evaluated.

It was also possible to deduce information about the temporal and geographic scope of the outputs from the statements that actors in the positions agreed upon (Table 1, S1-4). Here, the District's capacity to appropriate from the particular funds to cover or support specific activities is regulated.

The findings suggest that the District, the Board and other participating governmental entities were the key actors within the action arena deciding the budget for the years that followed the 2013 flood. Based on the analysis, these actors are expected to engage in accounting and budgeting activities to plan, coordinate and justify activities associated with the District's main function to plan, coordinate, maintain, and develop drainage facilities in the Denver Metropolitan Area.

Furthermore, the statements shown in Table 1 outline the steps needed to be accomplished before the budget for the year ahead can be passed. Each of these steps involves more than one individual. Following the example of Heikkila et al. (2011) joint activities are described as linkages between actors in an action arena (denoted L). The first set of linkages (L1) describes collective action taken to draft a budget. In this context, the District consults other participating governmental actors concerning their needs for drainage developments. L2, describes a set of

joint activities that involve the general public in the budgeting process. The overall budget (including mill levy) and more specific CIPs need to be presented and discussed at a public hearing. L3, describes the interactions between the District and the Board. The latter, as the governing body, is responsible for and thus has to authorize the budget for the year but also the spending activities. Any budgetary changes need to be authorized as well, i.e. joint projects and planning studies. L4, describes activities in which the Board audits the District's budgeting activities, for they, as the governing body, are then accountable to the state government (L5).

The analysis of the 2013 CAFR statements also highlights the lack of principal rules. In other words, the statements did not include the part known as "or else", which outlines sanctioning mechanism used to provide a strong initiative to comply with the agreed rules. Only a handful of statements included a deontic denoting that a particular action is required or prohibited. The majority of statements included neither and were classified as a strategy, a plan of action from which it is difficult to predict whether individuals will comply with the recommendations (Ostrom, 2005b: 16).

Action Arena	Rules
Aggregate	A1: Responsibility for Account Receivable
	A2: Responsibility Account Payable
	A3: Responsibility for Budget (estimate for future costs)
	A4: Responsibility for Setting Mill Levy
Choice	C1: Order the District can appropriate funds
	C2: Timing Payments to District
	C3: Maximising Interest Earnings
Information	I1: Maintain Financial Records
	I2: Report for Fiscal Year
Position	P1: The District's Administration
	P2: The District's Operation
	P3: The District's Governing Body
Scope	S1: Fund Accounting (Major Governmental-Funds)
	S2: Fund Accounting (Non- Major Governmental-Funds)
	S3: Fund Accounting (Other Funds)
	S4: Tax Accounting (Mill Levy)
Payoff	Y1: Payment Obligations (Liability) Others
	Y2: Payment Obligations (Liability) the District
	Y3: Entitlements Employee

Tab. 1: Summary of ABDICO-based analysis of financial reporting rules outlined in 2013 CAFR (UDFCD, 2014a)

The analysis of the Board meeting minutes highlights that a considerably small group of individuals representing the aforementioned key actors repeatedly engaged in these meetings. The evidence shown in Table 2 suggests that the record kept by the District's accountants to record all financial expenditures made and revenues received by the District is reviewed by the Board on a monthly basis (L4: Cash Disbursement). The District also approaches the Board almost monthly with requests to authorize plans to implement projects included in the CIP (L4: Joined Projects). However, the process to draft and agree the CIP for the years ahead stretches over a period of five months. Between August and September the District's staff evaluates the project needs by sending out request letters or a CIP Draft to the local governments (L1: CIP Request Letters). This gives them the opportunity to include or change drainage improvement projects in the CIP. In the next meeting in September a draft of the mill levy and budget for the year ahead is presented by the executive director on behalf of the District (L1: [Year] Mill Levy [Year] Budget). In October, the Board certifies the mill levy and budget for the following year (L3: [Year] Mill Levy [Year] Budget) after it has been verified in a public hearing (L2: [Year] Mill Levy [Year] Budget), which takes place prior to the Board meeting. After the overall budget is authorized, the draft capital improvement plan (CIP) is presented to the Board in November (L1: CIP [Period]). In December, the Board authorizes the CIP (L3: CIP [Period]) after it has been verified at a public hearing (L2: CIP [Period]). Approximately a year later, an independent auditor evaluates the accounts. The findings are discussed with the Board (L5: [Year] Accounts) and then published (L5: CAFR[Period]).

Month	Activities reported to Board				
	L1: Draft Budget	L2: Public Hearing	L3: Authorise Budget	L4: Internal Review	L5: Audit
01 Feb 2013				Cash Disbursement Joint Projects	2012 Accounts
21 Mar 2013				Cash Disbursement Joint Projects	2012 Accounts
18 Apr 2013				Cash Disbursement Joint Projects	
16 May 2013				Cash Disbursement Joint Projects	CAFR 2012
15 Aug 2013	CIP Request Letters			Cash Disbursement Joint Projects	
19 Sep 2013	2014 Mill Levy 2014 Budget *CIP Request letters			Cash Disbursement Joint Projects	
17 Oct 2013		2014 Mill Levy 2014 Budget	2014 Mill Levy 2014 Budget	Cash Disbursement Joint Projects	
21 Nov 2013	CIP 2013-17			Cash Disbursement	
19 Dec 2013		CIP 2013-17	CIP 2013-17	Cash Disbursement	

Tab. 2: CIP-related communication and deliberation activities as reported at Board meetings in 2013 (UDFCD, 2014b)

3.2   Discussion

These observations summarized in Table 1 and Table 2 suggest that the action arena in 2013 was grounded in a set of rules (primarily strategies) that facilitated communication and reciprocity between a small number of actors appointed to draft and authorize plans for capital improvements after the 2013 flood: First, rules were in place to ensure that the process of drafting the budget and subsequent CIP was transparent and accessible to all potential sources of information. Second, the existing rules facilitated communication and reciprocity between the key actors in the action arena, such as monthly reviews to monitor the Districts spending activities and plans. Third, the rules provided clear guidelines regulating the number of activities available to specific actorsc in this context (e.g. prepare repot for fiscal year). Fourth, the rules clearly stated who was to engage in these activities. Finally, the rules also maintain a system of checks and balances ensuring that the key actors are regularly held accountable for their actions (e.g. reviews and hearings). Thus, it seems fair to deduce from this that the actors operated under rules creating conditions favorable for the use of 'big data' to arrive at a quick and uncontroversial budgeting decision when confronted with shifting resource needs after the 2013 flooding event.

The minutes of the four Board meetings that took place between the flood in September and the adoption of the next CIP in December 2013 support this conclusion. The records mention that the fiscal resources funding infrastructure developments were limited and in order to add a new project, another project had to be omitted or postponed. Although the Board ultimately authorized the list of projects to which priority should be given in December 2013 (see Table 2, L3 "CIP 2013-17"), the plan itself was the outcome of a consultation process that involved the District and all other participating governmental entities. First, the District issues a call for funding applications a few weeks before the draft budget and mill levy for the coming fiscal year is presented in the September Board meeting (see Table 2, L1 "2014 Budget and 2014 Mill Levy"). As the area experienced heavy rain and catastrophic flooding between the 9th and 15th of September 2013, the District decided to resend their request for calls and initiated another consultation that took flood-related changes into account (see Table 2, L1 "*CIP Request Letters"). The record of the September 2013 meeting shows that the District initiated a second round of CIP requests to accommodate and/or prioritize flood related projects in the CIP (UDFCD 2014a):

„The District has worked closely with local governments to incorporate priority projects in the CIP, including incorporating follow-up requests that were submitted as a result of the 2013 flood. These draft plans will be sent out to our local government contacts for their review and comment."

According to David Bennetts, central to the discussion with the other participating governmental entities to prioritize projects are the planning studies that are available online (Bennetts Interview 23rd September 2013: 00:23:00), which are carried out to estimate the hazard and the costs of measures to mitigate the risk. The records of the Board meetings suggest that these planning studies are managed by highly specialized contractors and consultants in collaboration with the District, affected government entities, local inhabitants, and businesses that reside in the study area. The Board ultimately authorizes the research but also disseminates the final report. In other words, every other participating governmental entity could apply for funding support, but only projects for which planning studies have been concluded were considered. Although the consultation itself is not captured in the records of Board meetings, one can assume that any conflict at this stage would have surfaced in December when the District presented the agreed plan at the public hearing and to the Board for scrutiny and approval. No such conflict was recorded; suggesting that all actors arrived at a shared understanding of what projects should be prioritized for funding support within the time period available to them. This suggests that the conditions created by the funding rules were indeed favorable for the use of 'big data' in the aftermath of the 2013 Colorado flood.

4   Conclusion

These findings complement research suggesting that rules structure settings that can either facilitate or hinder actors from using information that other provide (Ingold, 2014; Heidrich et al., 2013; Satterthwaite, 2013). More specifically, the discussion contributes to the literature on 'big data' use in urban flood hazard mitigation in two ways: On the one hand, it highlights the need to identify the working parts of rules and to explore their influence on the use of 'big data' in specific action arenas. On the other hand, it adds to current case study material (Handmer, 1990; Grigg, 2011a, 2012) with an analysis of the rules structuring the use of 'big data' in developing capital investment plans for drainage facilities in the Denver Metropolitan Area after the 2013 flood. For example, the findings suggest that rules assign the District to activities related to the development of the ‚big data' asset, which explains why it is generally considered to be an information broker.

However, the here presented analysis gives only a very narrow snapshot of the situation. Further research is needed to analyze how specific rule configurations affect the use of ‚big' data over time.

Zusammenfassung

Dieser Artikel untersucht den Zusammenhang zwischen gemeinsam bestimmten Regeln und der Verwendung von „Big Data" in der politischen Handlungsarena des nachhaltigen Managements von Hochwassergefahren im Großraum Denver (US-Bundesstaat Colorado) - Ein Fall, der weltweit als Vorlage für Handlungsarenen in diesem Bereich verwendet wird. Die Analyse konzentriert sich insbesondere auf Rechnungslegungsvorschriften und deren Einfluss auf die Verwendung von „Big Data" im Zusammenhang mit Investitionsentscheidungen in den Monaten nach der katastrophalen Colorado Flut im Jahr 2013, welche Lücken im bestehenden Entwässerungssystems aufgezeigt hat.

Schlüsselwörter: Big Data, institutionelle Analyse, Hochwasserrisikomanagement

Résumé

Cet article examine le rapport entre les règles convenues d'un commun accord et l'utilisation de „Big Data" dans la tribune d`action politique de la question durable des risques d'inondation dans la région métropolitaine de Denver (Etats-Unis, État du Colorado) - Un cas qui est utilisé dans le monde entier comme un modèle de manœuvre pour les régions urbaines. L'analyse se concentre en particulier sur les normes comptables et leur effet sur l'utilisation de „Big Data" dans le contexte des décisions d'investissement dans les mois après la désastreuse inondation de Colorado en 2013, qui a mis en évidence des lacunes dans le système de drainage en vigueur.

Mots-Clé: big data, analyse institutionnelle, la gestion des risques d'inondation

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