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REVIEW

A review of approaches for monitoring and evaluation of urban climate resilience initiatives

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Abstract There are numerous challenges that evaluators face when determining the success of urban climate resilience initiatives (e.g., how to attribute impacts to initiatives). Fortunately, a growing body of literature—much of it dealing with climate change adaptation—has emerged which can help address these challenges. This narrative review of academic and grey literature reviews various monitoring and evaluation methods that can assess the inputs, processes, outputs, outcomes, and impacts that result from climate resilience planning and action. Since there is no commonly accepted monitoring and evaluation approach, the literature stresses the importance of acknowledging the context in which resilience is being evaluated, in order to ensure that appropriate methods are chosen. This context includes the ways that the resilience framework and definition chosen for a project constrain and determine the monitoring and evaluation approaches which can be adopted. As a result of this, a blend of quantitative and qualitative approaches is often recommended, with sufficient evidence suggesting that qualitative approaches (e.g., outcome harvesting) are essential. Nuanced approaches to monitoring and evaluation give evaluators additional means of reporting progress, and of demonstrating success, which is especially important as cities begin to implement resilience initiatives in the coming years.

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1 Introduction

Evidence of a changing climate (e.g., Rignot et al. 2013; Rockström et al. 2009; Szento et al. 2015) has led to an increasing amount of urban climate resilience research, planning, and action in Canada. This is reflected in Canada's 2016 Federal Budget, which includes the statement that "Canada's future prosperity rests on its ability to adapt to new challenges, including those that result from climate change and other threats to water and land" (Government of Canada 2016).

The metaphorical richness of the concept of resilience has led to its use in a number of discrete fields of inquiry (Tyler and Moench 2012). In the context of cities responding to the risks posed by climate change, most definitions involve a focus on urban systems (e.g., social-ecological) and their ability to recover from slow- and fast-onset climate pressures (IPCC 2014; Meerow et al. 2016). Some definitions are explicitly concerned with engaging vulnerable populations and social justice (Brisley et al. 2012; Cox and Hamlen 2015; Mulligan et al. n.d.; Arup and Partners 2015a). Many definitions involve an emphasis on capabilities and capacities before, during, and after a climate-related shock or stress (Bahadur et al. 2015; Béné et al. 2012; Mendis et al. 2003; Smit and Wandel 2006; Villanueva et al. 2015).

Climate resilience is typically differentiated from climate change adaptation on the grounds that adaptation is focused primarily on absorbing and/or avoiding harms from pending or predicted climate pressures (Climate-Eval 2015). Resilience is more broadly defined, such that it involves the various systems that affect the ability of a city to anticipate, absorb, and reorganize itself in relation to both known and unknown threats (Maru et al. 2014; Meerow et al. 2016; Mock et al. 2015; Moser and Boykoff 2013). While some Canadian climate adaptation projects are beginning to be completed (Warren and Eyzaguirre 2014), activity relating to urban climate resilience tends to be more preliminary, focusing on tools and frameworks which assess and encourage resilience (Cox and Hamlen 2015; Medellin Collaboration on Urban Resilience 2015).

Conceptualizations of resilience tend to focus either on the characteristics that precipitate resilience (e.g., flexibility, redundancy), the procedures and processes that precipitate resilience (e.g., effective stakeholder engagement), or on actual resilience outcomes (e.g., post-disaster recovery time) (Cutter 2016; Folke et al. 2002). Instead of offering a preferred definition, we flag these various approaches in order to explore monitoring and evaluations approaches related to each.

Resilience assessments tend to either measure "inherent" (i.e., existing, baseline) resilience, or assess it after a disaster has occurred (Cutter 2016). Some resilience assessments focus on physical infrastructure (AECOM and Risk Sciences International 2015; Siemens 2013), while others seek to use standardized methods that enable comparisons between different cities, for example, the impressive assessment work done by ND-GAIN, the World Council on City Data, and the STAR Community Rating System. In terms of encouraging movement from assessment to planning (called "capacity building tools" by Cutter 2016), the most prevalent tools for large cities are UNISDR's Resilient Cities and the City Resilience Framework, deployed by Rockefeller Foundation's 100

Resilience Cities program. At a smaller scale, the American Council for an Energy-Efficient Economy has just created a program to help smaller cities connect their energy efficiency goals to resilience planning (Ribeiro et al. 2015).

Alongside infrastructure assessments and action plans, the building sector is also starting to acknowledge the importance of resilience action (City of Toronto 2016; Judah and Cousins 2015). For example, Canada's leading new building certification system (i.e., LEED) is currently piloting methods by which to reward buildings for assessing and deigning for resilience, for example, by increasing storm water retention, or reducing the urban heat island effect (Wilson 2015). BOMA BEST, which assesses and certifies existing buildings, has made similar changes.

Evaluation methods (e.g., plan evaluation) exist for assessing climate adaptation plans across multiple criteria (Woodruff and Stults 2016). Similarly, the adaptation community is acutely concerned with how to determine the success of adaptation initiatives (Moser and Boykoff 2013). An increasingly active area of inquiry (e.g., Cutter 2016) involves how to overcome the various monitoring and evaluation challenges that arise when assessing the efficacy of the inputs, processes, outputs, outcomes, and impacts that result from climate resilience planning, with many authors stressing the urgency of this endeavor (Bahadur et al. 2015; Linkov et al. 2014). Evaluation empowers programmers to improve existing initiatives and to influence future ones, as well as enabling the production of evidence-based claims, which are essential in supporting decision making. What follows is a review of the challenges and opportunities currently faced by the resilience evaluation community, many of which come from the climate change adaptation literature.

2 Methods

The review presented here employs a narrative scoping review approach (Davis et al. 2009) in which a narrative style is used to present the state of resilience evaluation research and to make suggestions to guide further work. Scoping reviews "tend to utilize a wide range of research and non-research material within the review" (Rumrill et al. 2010). As such, this review includes both gray and academic literature. The academic sources consulted in this review represent the following literatures: climate change adaptation, climate resilience, international development, planning, and disaster risk management. Roughly 50 academic sources were consulted during the review process.

The gray literature used in this review draws largely from what Moser and Boykoff (2013) call a "growing guidebook literature" that is focused on "processes and metrics for monitoring and evaluating progress toward defined adaptation outcomes." Though some sources explicitly strive to guide climate resilience monitoring and evaluation, much of the content of this review comes from the climate change adaptation literature. Notwithstanding the origins, there are limitations as to the conclusions that ought to be drawn from the gray literature, especially that which has not been peer-reviewed. In order to counteract this, every effort was made to consult authors who have an established reputation in this field (e.g., demonstrated by a long publication record, presentations at established conferences) and whose work can therefore be reasonably relied upon. The authors feel that the combination of academic and gray literature presented in this review is ideal in understanding the monitoring and evaluation challenges faced by those who will be evaluating resilience initiatives in North American urban contexts in the coming years (see Fig. 1).

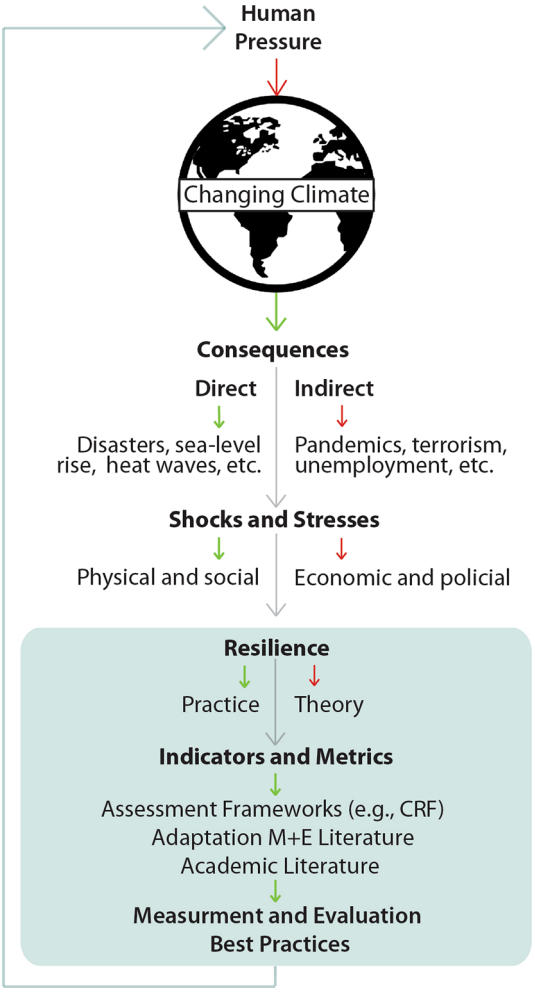

Fig. 1 Scope of inquiry for this review. *Green arrows* represent areas which have been included, and *red* represents those which have not

3 Results and discussion

3.1 Determinants of resilience

The purpose of this section is to outline various determinants of resilience, in order to underpin some of the evaluation challenges and opportunities that will be discussed in subsequent sections. As mentioned above, some resilience initiatives aim to improve critical infrastructure, the outcomes of which are relatively simple to assess (e.g., via calculations). However, the resilience of critical infrastructure is a necessary, but not sufficient condition of urban resilience (Arup and Partners 2015a).

Resilience is often thought of as an amalgam of multiple capitals, primarily human, social, natural, built, and economic (Burton 2015; Cox and Hamlen 2015; ICLEI–Local Governments for Sustainability, n.d.; Arup and Partners 2015b). Natural capital refers in part to the ability of natural features (e.g., wetlands) to buffer against climate-induced risks (e.g., overland flooding) (Feltmate and Thistlethwaite 2012; Ibarraran et al. 2010). Built

capital generally refers to nonnatural, physical features which are essential in mitigating climate risks (e.g., dykes, buildings). Economic capital refers to the economic resources, at multiple levels, required to ensure resilience. Human capital refers to the knowledge, skills, and capabilities of individuals and small groups (Cox and Hamlen 2015).

Social capital, which is an emerging area of importance in the literature, is defined as the "the links, shared values and understandings in society that enable individuals and groups to trust each other and so work together" (Keeley 2007). Social capital was shown to be important in the recovery after Hurricane Sandy, where it was found that "people living in neighbourhoods with more social connections were more resilient" (The Associated Press-NORC Center for Public Affairs Research 2014). But incorporating "social resilience" into planning and action is difficult (Carpenter 2015; Patwardhan 2016). Many of the nonphysical capitals are often ignored and unnoticed due to the complications related to identifying and measuring them (Jones 2016; Arup and Partners 2015a).

In addition to the various capitals, resilience is often thought to be comprised of various capacities (Climate-Eval 2015; Ibarraran et al. 2010). For example, for Bahadur et al. (2015a, b), resilience is comprised of adaptive capacity, anticipatory capacity, and absorptive capacity (i.e., the "Three A's"). The ability to transform (i.e., transformative capacity) is sometimes distinguished from adaptive capacity (Lonsdale et al. 2015), but this has yet to be resolved in the literature. Notwithstanding this point, these capacities are important to flag as they usher in specific monitoring and evaluation opportunities that will be discussed.

Resilience is also commonly thought to be determined by the characteristics, or qualities of various system components and/or capitals. For example, the City Resilience Framework has four dimensions (see Table 1), with which 12 drivers (similar to indicators) are associated. For each of these drivers, there are seven qualities that should guide planning (Arup and Partners 2015a). These qualities are: reflectiveness, resourcefulness, robustness, redundancy, flexibility, inclusiveness, and integration. Referring to the use of the seven qualities, the City of New Orleans (2015) writes that "at each stage of the process, we also relied on the qualities of resilient systems as a touchstone to guide the development of our

Table 1 Dimensions and drivers used in Rockefeller Foundation's City Resilience Framework

Health and well-being
1. Meets basic needs
2. Supports livelihoods and employment
3. Ensures public health services
Economy and society
4. Promotes cohesive and engaged communities
5. Ensures social stability, security and justice
6. Fosters economic prosperity
Infrastructure and environment
7. Enhances and provides protective natural and man-made assets
8. Ensures continuity of critical services
9. Provides reliable communication and mobility
Leadership and strategy
10. Promotes leadership and effective management
11. Empowers a broad range of stakeholders
12. Fosters long-term and integrated planning

actions." The City Resilience Framework presupposes that by monitoring and evaluating these characteristics and qualities, one is implicitly measuring resilience.

3.2 Resilience assessment frameworks

In 2014, The Guardian reported that Toronto had been named the most resilient city in the world (Michael 2014). This result was produced by Research Group of Grosvenor Group Limited (2014) using a method which collected the same vulnerability and adaptive capacity data in fifty of the world's most important cities. These indicator data (e.g., efficacy of disaster management planning) were statistically transformed into standardized units (i.e., z-scores which can then be weighted), and then summed into an index score, enabling cities to be ranked. This is the same approach taken by the World Council on City Data (WCCD) and the International Organization for Standardization (ISO) in their collaboration on a forthcoming resilience standard which, by enabling comparisons and benchmarking, will help increase the insurability and credit-worthiness of participating cities (McCarney 2014). Though quantitative approaches have led to some important progress, there are those who build on the warnings originally offered by Meadows (1998), raising potent objections to quantification (e.g., Cox and Hamlen 2015), and lamenting that "by summarising data into a single quantitative score, indices take on an objective authority that commands, but does not necessarily merit, respect" (Arup and Partners 2014). The rest of this review will focus on resilience tools which focus more on planning and action processes, and which include both quantitative and qualitative indicators.

3.3 Monitoring and evaluation

Pringle (2011) offers three ways to monitor and evaluate climate adaptation, all of which are applicable to resilience: (i) measuring against the objectives of the intervention, (ii) measuring against emerging understanding of good adaptation, and (iii) measuring against a baseline.

3.3.1 Measuring against baselines

The use of baseline comparisons is an essential strategy in evaluating the outcomes and impacts that result from resilience initiatives (e.g., Cutter et al. 2010; ICLEI–Local Governments for Sustainability, n.d.). During this process, an initial measurement is taken (e.g., number of civic organization per 10,000 people). This measurement is then taken again at various intervals in order to assess the success of strategies which have aimed to improve this particular indicator. This approach could be applied more generally to the three capacities described above, or even to the resilience characteristics (e.g., flexibility). In order to do this, a more qualitative assessment (e.g., a subjective ranking from 1 to 5) could be used to create a baseline value.

A key challenge when using baseline measurements is the issue of shifting baselines, which happens as a result of changing conditions in complex systems over time. For instance, if one was tracking the percentage of wetlands relative to total area in a given location, the logically desired resilience outcome would likely be an increase in wetlands. However, perhaps a successful outcome would have been for the percentage of wetlands to stay the same, as a result of conditions for wetlands deteriorating overall (Climate-Eval 2015). On paper, there would be no change in conditions pre- and post-intervention, but in

reality, a success had been achieved. By using dynamic baselines, or at least being cognizant of this phenomenon, evaluators can make more robust assessments (Villanueva 2011). Similarly, Constas (2015) urges evaluators to consider what the expected rate of change for a certain phenomenon is. For example, encouraging neighboring municipalities to create collaborative relationships does not happen immediately, but waiting five years to take a measurement is too long. Knowing the appropriate time frame is essential in making comparisons against a baseline.

3.3.2 Measuring against definitions

The second of three measurement methods advocated by Pringle (2011) is "measuring against emerging understanding of good adaptation." While relatively straightforward definitions exist for climate adaptation (e.g., de Franca Doria et al. 2009), in the context of resilience—with its emphasis on system-level interactions and inherent qualities (Mock et al. 2015)—this measurement approach is much more difficult. Indeed, the way that one defines resilience is a key determinant in the monitoring and evaluation approach adopted. For example, when resilience is defined as a decrease in post-disaster recovery time, specific indicators will be evaluated that would not be useful in a scheme which was concerned with the characteristics of resilience with cities.

This is further complicated by those who advocate that the determination of success is, or ought to be, contingent and contextual (Adger et al. 2005). This is often articulated as the problem of "resilience for who?" (Meerow et al. 2016). Moser and Boykoff (2013) write that "success is not simply to be decided on scientific, rational, objective, or procedural grounds, but is in important ways normative, historically contingent, and context-specific." For example, Adger et al. (2005) write the effectiveness of adaptation can be assessed in reference to equity, legitimacy, or economic efficiency. These "normative agendas" (Alexander et al. 2016) (i.e., legitimacy, equity, and efficiency) can be used as a wholly alternative means by which to assess the outcomes of resilience actions. For example, "equitable adaptations can be evaluated from the perspective of outcome (i.e. who wins and loses from the adaptation) as well as who decides on the adaptation to take" (Adger et al. 2005).

Indeed there are even other storylines against which resilience initiatives could be evaluated. For example, Adger et al. (2005) create evaluation premises based on four "storylines of development" from the IPCC process. Initiatives can be evaluated based on the development narratives outlined therein, providing another normative arena in which to assess success. The monitoring and evaluation challenge grows when we consider that the so-called transformative capacity implies that resilience actions contribute in some way to the requisite, systemic transformations required to ensure our continued well-being (Lonsdale et al. 2015). This marriage between resilience, adaptation, and low-carbon development paths can also be seen in the emerging field of low-carbon resilience (Nichol and Harford 2016; Wise et al. 2014) and adds another layer of complexity for those seeking to measure the success of resilience initiatives in relation to accepted definitions.

And so, deciding on how resilience will be defined is an essential step in designing both the outputs that will be generated, and the means by which their impact can be assessed. When one selects an existing framework, for example, the City Resilience Framework, one inherits their conceptual preoccupations—in this case the characteristics of resilience—and also the means by which they will be assessed (i.e., specific indicators). One qualitative approach that can be used to create or augment a context-specific definition of resilience is the Delphi method (de Franca Doria et al. 2009). During this process, successive rounds of

questionnaires are delivered to participants who are asked to agree with iteratively refined statements (e.g., "successful resilience means…"). Once a predetermined level of consensus is built, the issue (in this case, what resilience ought to encompass) is considered closed.

3.3.3 Measuring against project objectives

The third approach advocated for by Pringle (2011) is to measure against project objectives. As alluded to above, the objectives of a resilience program depend on how resilience is defined, and at what point in the temporal scale one is intervening or assessing. Alexander et al. (2016) define process as the "inputs, throughput and outputs of the decision-making process," outcomes as "the implementation of the outputs from the decision-making process" and impact as "the resulting effect of the decision-making process and outcome" (see Fig. 2, for an example). Similarly, Spearman and McGray (2011) use the following sequence: inputs, initiatives, outputs, outcomes, and impacts. Monitoring and evaluation can take place at each of these temporal locations (i.e., process, outcome, impact). Indeed, there are those who advocate that monitoring and evaluation be incorporated throughout the project, instead of just at the beginning and at the end, even borrowing practices from developmental evaluation where the evaluator is embedded within the process, instead of a third party to it (Eyzaguirre 2016).

3.4 Approaches to measurement

3.4.1 Quantitative indicators

OECD (2002) defines an indicator as a "quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention, or to help assess the performance of a development actor." Quantitative indicators are numerical representations of complex phenomenon (e.g., percentage increase/decrease, ratios, absolute numbers) (Climate-Eval 2015; USAID 2009). Quantitative indicators can be useful at all temporal stages of a resilience project and could even be useful in assessing the strength of resilience characteristics, though this is often better accomplished through the use of qualitative indicators.

3.4.2 Qualitative indicators

Qualitative indicators report the quality of a given entity, often using subjective data (i.e., relying on subjects [people] instead of objects [instruments]). Many indicators use a

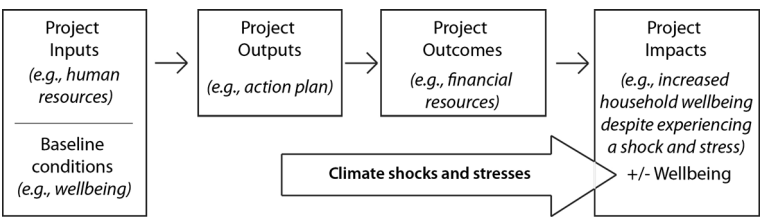

Fig. 2 Four phases of a resilience initiative, and the timing of baseline and post-shock measurements of well-being. *Adapted from* Department for International Development (2014)

qualitative 1–5 scoring system (ICLEI–Local Governments for Sustainability, n.d.; UNISDR 2015). This is not the only way; Sovacool (2012) points out that indicators could "rely on a simple scoring technique of 'positive,' 'negative,' or 'neutral,' as in a given metric can worsen, improve, or stay the same over time."

These qualitative values can be used to create baselines and/or to indicate that a resilience outcome/impact has been achieved. Of course, the challenge with a qualitative indicator that uses a scale of 1–5, for example, is that the scale needs to be created in such a way that its criteria are fair, well informed, and replicable. Both the City Resilience Framework and the UNISDR Ten Essentials provide evaluators with examples of qualitative scales that can either be used outright, or to guide the creation of bespoke scales.

FSIN Resilience Measurement Technical Working Group (2014) points out that subjective assessment of resilience—such as perceptions of shocks and stresses—should be included in assessments of resilience. Subjective data can be very useful for uncovering changes in social and human capital (e.g., trust, risk perception, power dynamics) (Maxwell et al. 2015) as well as complex socioeconomic dynamics (Bours et al. 2014b). An aversion to qualitative and/or subjective indicators can obscure "key determinants of human equity and action" (Hicks et al. 2016). Sovacool et al. (2015) warn against a "preponderance of quantitative perspectives, mapping a general tendency to propose technical solutions to social problems."

Reporting on work carried out by Oxfam, Fuller and Lain (2015) give the example of using "anchoring vignettes" to get respondents to rate a hypothetical resilience scenario, which is then compared to respondents' rating of their own resilience. In doing so, researchers hope to calibrate the respondent and give the assessor a sense of that calibration, thereby corroborating the subjective assessment. This type of approach could be used alongside other types of indicators, allowing evaluators to ensure that quantitative and qualitative indicators are aligned with the subjective experiences of community members.

3.4.3 Process indicators

As shown in Fig. 2, monitoring and evaluation can take place in relation to the processes that underlie resilience, the outcomes of resilience planning, as well as the impacts of resilience initiatives. This can be done using quantitative and qualitative indicators, as well as other approaches discussed below. The first approach to be discussed is the use of process indicators. There are many processes that underlie resilience planning and action, and process indicators are created to reflect the extent to which these processes have been undertaken. Moser and Boykoff (2013) write that given the challenges (e.g., attribution) in adaptation and resilience measurement, "tracking and evaluating the adaptation process—with all of its individual components (e.g., assessment, planning, stakeholder engagement, decision-making, implementation, institutionalization, monitoring, and social learning)—becomes at least as important as the questions of success in outcomes" (emphasis in original).

As Climate-Eval (2015) points out, there are two ways that process indicators are generally thought of. One school claims that they are meant to measure progress along a series of steps toward a desired outcome (e.g., striking a committee), whereas the other involves qualifying the merits of these processes vis-a-vis resilience goals (i.e., are they the right processes?). Though both are pertinent, the former is the one which is explored here.

A simple example of a process indicator is the extent of participatory involvement in resilience decision making. That is, if one's definition of resilience espouses participatory involvement, then the extent to which this has been instantiated can be used as a process

indicator. This could be assessed qualitatively (e.g., 1–5 scale) or quantitatively (e.g., # of stakeholder types represented). Schipper and Langston (2015) offer another salient example, writing that if learning is identified as an important driver of resilience, then measurement could include the extent to which information sharing and awareness raising has taken place. They point out that "at the same time, this type of activity may be considered an output if we are interested in measuring project success" (Schipper and Langston 2015). Notwithstanding this distinction, when looking at behavior change as an outcome of a program, practitioners need to consider many aspects of evaluation, including longitudinal methods for monitoring and evaluating behavior, and assessing causal links (Climate-Eval 2015). In this sense, scope matters, and an understanding of why processes are important is essential is the creation of indictors.

Similar to the measurement of resilience characteristics, the use of process indicators can address the problem whereby it is difficult to measure resilience in an a priori manner, that is, before extreme events have occurred (Bahadur et al. 2015; Wilson et al. 2016). Another common way that this problem is addressed is through the use of counterfactual analysis, whereby evaluators determine the consequences of a shock or stress in the absence on an initiative (e.g., a dyke) and use that as the basis of quantifying successful outcomes and impacts (Bours et al. 2014a, b; Climate-Eval 2015). Counterfactuals can also involve a process by which the impact of a project is "compared with a 'counterfactual' scenario in which the same shock or stress occurred but in which the project had not been implemented" (Brooks et al. 2014).

3.4.4 Outcome harvesting

Eyzaguirre (2015) sought to evaluate the influence of NRCan's Regional Adaptation Collaboratives (RAC) in terms of their immediate effect on encouraging collaboration and decision making and in terms of their influence after program deployment. In order to do this, the program employed a research method called outcome harvesting, where "outcomes are defined as changes in the 'behaviour writ large' (such as actions, relationships, policies, practices) of one or more social actors influenced by an intervention" (Wilson-Grau 2015). Outcome harvesting is "suited to examining program impact on issues defying traceability" (Eyzaguirre 2015), in this case the likelihood that the RAC will lead to increased adaptive capacity in the future.

To do this, two subjective sources of data were consulted: final reports from RAC participants, and interviews with key personnel that asked about the most exciting or successful thing that had happened in their jurisdiction as a result of the RAC program (Eyzaguirre 2016). These data indicated the outcomes (e.g., recruitment of local champions) had emerged which could reasonably be thought to engender successful adaptation efforts in the future (Eyzaguirre 2015). Though quantified outcomes are often required by decision makers, it is often case that the existence of these preliminary outcomes—and/or processes—is the only data that exist at certain points in the project (Eyzaguirre 2016).

White and Phillips (2012) provide an overview of additional methods that can be used to address the attribution problem when small samples and no control groups make statistically significant testing impossible. The methods discussed are separated into two groups, one which is preoccupied with hypothesis testing and those that are more preoccupied with incorporating stakeholders into the evaluation process. In the first group are methods including realist evaluation, general elimination methodology, process tracing, contribution analysis (White and Phillips 2012). The second group includes most significant change (which is very similar to outcome harvesting), the success case method,

outcome mapping, and method for impact assessment of programs and projects (MAPP). The reader is directed to White and Phillips (2012) for a complete discussion of these methods which could be used to demonstrate the success of a resilience initiative in the near term, and/or where access to quantitative outcome and impact data is limited.

3.4.5 Selection of indicators

There are numerous indicator creation schemes that evaluators can use to create bespoke, project-specific indicators, many of which are described in Annex C of Climate-Eval (2015). For example, Villanueva (2011) created the ADAPT scheme—which advocates for indicators that are adaptive, dynamic, active, participatory and thorough—in order to add some flexibility to the prominent SMART regime. Tyler et al. (2016) combine SMART and ADAPT principles and insist that "the process of developing indicators should be iterative, collaborative, and deliberative to gain the maximum benefit of shared understanding and buy-in."

It is also often useful to create indicators which blend quantitative and qualitative (e.g., number and quality of outreach initiatives). A related strategy is the use logframe indicators (i.e., logical framework indicators) which "focus on aligning the component parts of a programme into a hierarchy of clearly-specified goals, outcomes/objectives, outputs/results, inputs/activities, (usually) together with a set of measurable indicators to demonstrate progress" (Bours et al. 2014b). Logframes usually include process and outcome indicators, and force evaluators to clearly define what success looks like in a given context.

It is often prudent to use existing indicators instead of creating bespoke ones. This can lead evaluators to harvest indicators from existing resilience frameworks. This should be done judiciously, as indicators from large resilience planning frameworks (e.g., City Resilience Framework) may not be appropriate or feasible for different settings (e.g., a medium-sized community). Moreover, the framework chosen necessarily influences and constrains the types of monitoring and evaluation that are carried out. For example, if the Ten Essentials program identifies "presence of grassroots organizations" as an indicator of social capital, and then the evaluator will have no choice but to assess it in the same way, regardless of its applicability for their particular context (UNISDR 2015).

As Tyler et al. (2016) point out, standardized indicators and broad planning frameworks can distract from the city's contextual mix of systems and vulnerabilities, drawing the resilience enterprise into jeopardy. Jones (2016) urges that it is often the case that people know what is best for them and that imposing a large "objective" framework on them could miss the point entirely.

Evaluating the outcomes of resilience processes can be relatively straightforward. For example, Béné et al. (2012) point out that the intuitive nature of resilience has led to its adoption as a policy narrative, which in turn has brought together a diversity of stakeholders. "Resilience-as-galvanizing-agent" could be measured in the creation of new institutional arrangements, policies, etc. Spearman and McGray (2011) urge evaluators to consider whether the outcomes are going to be practical (e.g., number of culverts) or conceptual (e.g., resilience), as this influences the type of evaluation used.

3.4.6 Impact indicators

Determining the actual impact of resilience initiatives is difficult because these impacts are often enigmatic, emerging in complex systems and can often not be measured until after a disaster, or until at least some of the slower onset effects of climate change (e.g., sea level

rise) have been experienced. One approach could involve summarizing the performance on the various process and outcome indicators which were measured during a project and inferring from these results that resilience is more or less reasonably assured. While this approach is common and can yield valuable insights about the resilience of a particular system, it does not actually measure the impacts of resilience, per se (e.g., post-disaster recovery time).

Brooks et al. (2014) suggest that well-being and financial losses resulting from disaster are the two central climate resilience indicators that allow cities to assess the impacts of resilience initiatives. By monitoring these indicators, evaluators gain access to sources of evidence about the effects of resilience initiatives in the community. Granted, there will be considerable noise in these data, especially if there are numerous resilience initiatives operating (to say nothing of programs aimed at improving adaptation, or sustainability, or economic inequality). But by measuring these two indicators, a city can quickly determine whether they have sufficient anticipatory, absorptive, and adaptive capacity to remain resilient in the face of shocks and stresses relating to a changing climate.

Since cities are in part financial systems, it makes sense to track the economic performance of communities in relation to climate shocks and stresses. Various metrics have been suggested for this purpose, but most focus on the dollar amounts associated with response and recovery. These are sometimes normalized using population (e.g., per capita economic loss). This also gives a community the means by which to assess their return on investment for adaptation and resilience actions, and to indicate the overall health of their economic systems in relation to climate risks.

Because cities are not solely economic systems, it is important to also monitor well-being in order to use it as an indication of whether efforts to increase resilience have been successful (Armitage et al. 2012; Constas 2015; Department for International Development 2014; McGregor et al. 2015). The general thinking is that even physical infrastructure is meant to contribute to human well-being (e.g., by removing sewage) and therefore well-being is an accurate measure of the impact of resilience initiatives. Well-being measurements can also be used in a pre-/post-design where levels before, during, and after a shock or stress can be measured and compared as a means of demonstrating the impacts of specific initiatives (see Fig. 2). Established methods exist by which to measure well-being (Hicks et al. 2016; OECD 2013), and leveraging these established social theoretical frameworks is generally thought to be a good thing (Béné et al. 2012).

Schipper and Langston (2015) add some perspective to this discussion, finding "that resilience cannot be measured only through indicators of improved livelihoods and well-being, but that it also cannot be measured without such information." Similarly, Bours et al. (2014a) suggest that instead of trying to directly attribute a program to an end-state (e.g., resilience), it is usually better to situate progress made by the program within broader urban resilience and climate adaptation goals.

4 Discussion

Ultimately, the decision of which monitoring and evaluation tools should be used is driven by the framework that has been adopted and/or the resilience priorities of the community. Bours et al. (2014b) report that most resources urge evaluators to ask the right questions and that qualitative, quantitative, and binary indicators should be used to complimentarily. Because robust processes could be insufficient in achieving outcomes—and because

inferior process could lead to desires outcomes—"policy-makers and scientists may require integrative indicators of success that include both process and outcomes observed at any one time and together paint a nuanced, if temporary picture of an 'outcome gestalt'" (Moser and Boykoff 2013). In other words, an evaluator must triangulate to the extent possible in order to arrive at a nuanced evaluation of a resilience situation.

Clean Air Partnership and ICLEI (n.d.) highlight a few of the practical challenges that resilience evaluators face: namely that "measurement may involve a range of stakeholders" that "M&E is not incorporated into project design" and that "obtaining data may be expensive, complex, and difficult." These challenges exist for both quantitative and qualitative indicators, and often involve trade-offs. For example, more participatory forms of program development and evaluation can empower stakeholders, but the means by which this is achieved are often expensive, complex, and difficult. In this sense, evaluators should strive to be at once idealistic and pragmatic. They should strive to instantiate the loftiest goals (e.g., increased well-being, equity) while also guarding against overly complicated evaluation approaches that can at least obscure the extent to which these impacts have emerged, and at worst stifle them from emerging in the first place.

Ultimately, though, the monitoring and evaluation scheme should be adopted based on its appropriateness for the context, and for its capacity for precision and accuracy, explanatory power, parsimony, and utility (Constas 2014). This is especially important due to the fact that resilience initiatives are often informed by social justice agendas and seek to ensure that climate resilience is not yet another activity which leaves marginalized groups of people behind (Cox and Hamlen 2015). The extent to which social and political barriers, and resilience actions themselves, exclude marginalized and vulnerable groups is an emerging research area, and one beset with its own measurement challenges (Anguelovski et al. in press; Bahadur et al. 2015; Chelleri et al. 2015).

In addition to the recommendations outlined above, the following is a list of things which evaluators should keep in mind as they design resilience initiatives, and/or the means by which they are monitored and evaluated:

- Evaluators need to determine the level of rigor required by their program and choose an evaluation framework accordingly;
- Ensure that resilience evaluations include key determinants of equity and action (Hicks et al. 2016; Cox and Hamlen 2015);
- Strive to educate decision makers on the merits of the various approaches to program evaluation;
- Instead of simply reevaluating indicators annually, FSIN Resilience Measurement Technical Working Group (2014) advocates that measurement interval frequency should be based on expected rates of change for each indicator (e.g., after every major rain event);
- Remember that there is a spatial element to resilience measurement, resilience affects each part of a community differently (Cox and Hamlen 2015);
- Evaluators should strive for parsimony; in an effort to avoid the "analysis paralysis trap" whereby mountains of data consume resources and prevent actionable outcomes. Schipper and Langston (2015) remind us that approximate answers to some important questions are better than exact answers to many unimportant ones;
- Know what you are not: Though resilience often alludes to a commitment to social justice, poverty reduction, for example, is not always well addressed under this paradigm (Béné et al. 2012);

- Constas (2015) asserts that monitoring and evaluation activities should illustrate both simple relationships, and complex, nonlinear ones.

5 Conclusion

Although contested in the literature, one of the main benefits of the resilience formulation, as opposed to the adaptation one, is its ability to evaluate outcomes and impacts in a relatively short-time frame, and in the absence of shocks and stresses. However, Cutter (2016) correctly highlights that "there is no panacea or one size fits all tool to measure resilience due to the range of actors, environments, purposes, and disciplines involved." Sophisticated monitoring and evaluating strategies need to be considered in order to enable evidence-based decision making and to establish best practices (Béné et al. 2012; Constas 2015). The challenges pertaining to monitoring and evaluation vary depending on the evaluation context, the framework or definition chosen, and the ability to access key data. It is important that evaluators strive to strengthen both the paradigm and practice of resilience, and also the methods by which it is monitored and evaluated. This is especially important as this field of practice moves from implementation to evaluation in the coming years.

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