COMPACT I:

Public Administration in Complexity

Edited by:
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Chapter 5

ASSESSING THE APPLICABILITY OF QUALITATIVE COMPARATIVE ANALYSIS FOR THE EVALUATION OF COMPLEX PROJECTS

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This paper introduces and assesses Qualitative Comparative Analysis (QCA) as a complexity-informed framework for evaluating complex infrastructure projects coupled with area development. This is done in four steps. First, the properties of infrastructure and area development are discussed. When combined with a complexity perspective, it follows that the context of a project is explanatory for its outcomes. Secondly, prerequisites for a evaluation framework following this point of departure are developed. Thirdly, common infrastructure evaluation methods are assessed against these requisites. It follows that a comparative case-based approach is most suitable to study the relationships between context and outcomes in projects. Fourthly, fuzzy set Qualitative Comparative Analysis (fsQCA) is introduced and assessed related to the developed requisites. The paper concludes with a discussion of the further development of fsQCA.

ISSUES IN ASSESSING TRANSPORTATION INFRASTRUCTURE PROJECTS

Transportation infrastructure projects are characterized by a lingering history of budget overruns, time delays and public resistance. The Dutch Elverding Committee concluded that decision making on infrastructure development in the Netherlands takes 11 years on average (Advisory Committee VBI, 2008), and Flyvbjerg *et al.* (2003a) found that cost overruns above 40 percent are common and that cost overruns above 80 percent are not uncommon. A European study more than a decade earlier showed similar results (WRR, 1994). Already in the 1970s and 1980s the effectiveness, efficiency and legitimacy of infrastructure development was heavily debated (De Hoo, 1982). This indicates that the complexity underlying infrastructure development is persistent and that there are no quick fixes to the issues associated with such development. This instigated a continuous analytical and professional search for a better understanding of infrastructure development, both in terms of causes and solutions. For instance, the Netherlands Institute for Transport Policy Analysis (KiM) strongly advocates the need for more and better infrastructure development evaluations (especially ex-post) emphasizing the need for a better understanding of why projects perform as they do (KiM, 2009). However, as also noted by Flyvbjerg *et al.* (2003a), it is more difficult to assess 'what' causes than 'that' causes. Hence, evaluation tends to be focused on comparing before and after, often inadequately incorporating the influence of contextual local conditions to infrastructure projects (Sanderson, 2000). According to Sanderson (2000), dominant evaluation methodologies impede policy learning since these account insufficiently for the complex nature of the policy system. Similar issues are raised by KiM, which states that ex-post evaluations are not just performed marginally, but that current evaluations are subject to methodological deficiencies (KiM, 2009; PBL & KiM, 2010), which can be related to the misfit between the way infrastructure development projects are understood and the methodologies used to evaluate them. Consequently, there is a need for evaluation methodologies that do justice to the complex nature of infrastructure projects.

In-depth case studies can pay ample attention to the contextual nature of such projects. However, evaluation aims to improve present infrastructure development practice and this requires transferability of lessons learned, and focusing on one particular context of one particular case does not allow analyzing patterns that may reoccur over different cases. At this point, the requirements of contextuality and generalization seem to be at loggerheads with each other, as will be shown in the next section. On the one hand, current dominant methods often fall short in terms of discounting local conditions in cross-case comparative studies. On the other hand, generalization is difficult from in-depth case studies. This paper introduces and assesses Qualitative Comparative Analysis (QCA) as a research approach for evaluating complex infrastructure projects that aims to reconcile the above dilemma. It combines a focus on generic patterns that are researched in variable-oriented studies with a focus on idiosyncratic events researched in case-based studies. However, before presenting this method, it is first necessary to elaborate our understanding of complex infrastructure projects, since establishing a fit between this and the method presented is pivotal. Hence, this article aims to answer the following question: what are the ontological, epistemological and methodological components of a method for assessing how both idiosyncratic events and recurring patterns influence transportation infrastructure development projects, and what should a coherent evaluation method based on these components consist of?

GENERALIZATION VERSUS CONTEXTUALITY IN TRANSPORT INFRASTRUCTURE STUDIES

Flyvbjerg *et al.* (2003a; see also Flyvbjerg *et al.*, 2002, 2003b, 2004, 2005; Flyvbjerg, 2007b, 2009; Næss *et al.*, 2006) performed a large quantitative comparative study of 258 large infrastructure projects in 20 different countries. The study revealed a number of patterns. For instance, actual costs are on average 45 percent higher than estimated, cost overrun is a global phenomenon and cost performance has not improved over the past 70 years. Although this study and its findings are of indisputable importance in accounting for the 'that' of infrastructure development performance, it cannot, as stated by Flyvbjerg *et al.* (2003a), explain the 'what' of cost overrun. Albeit they discern some more specific patterns by distinguishing, among others, between rail, road and fixed link projects (and between different types within these categories), this large-N study, by its very nature, cannot account in great depth for the influence of local conditions on cost performance. For example, Flyvbjerg *et al.* (2003a: 19) state that:

> *For the Channel Tunnel, changed safety requirements were a main cause of overrun. For the Great Belt link, environmental concerns and accidents with*

flooding and a devastating fire made the budget balloon. For the Øresund link, it proved more costly than estimated to carve major new transport infrastructure into densely populated Copenhagen, and so on.

In general, the study points to many similarities amongst projects in terms of their performance. For instance, the Øresund link and Channel Tunnel are quite similar regarding the percentage of cost overrun (i.e., respectively 70 and 80 percent) (Flyvbjerg *et al.*, 2003a). However, the causal paths leading to those results are different. An ex-post evaluation performed by Anguera (2006) into the cost performance of the Channel Tunnel reveals that, in addition to the findings of Flyvbjerg *et al.*, it is a combination of factors leading to cost overrun, for instance: a clear project owner was absent from the outset, the unforeseen advent of low cost airlines led to reduced ridership, political events between the French and British governments, difficult ground conditions, transport related incidents such as the PanAm crash at Lockerbie, and so forth. Obviously, although similarities undoubtedly exist, such specific conditions often cannot account for the cost overrun for the Øresund link project.

This brief example illustrates the tension between generic patterns and contextuality. Large-n quantitative studies such as those performed by Flyvbjerg *et al.* provide lasting insights into generic patterns such as cost development. The downside is that these studies do not allow analyzing the idiosyncratic nature of such projects in detail, while specific events may significantly contribute to project outcomes. Studies such as those performed by Anguera are case-oriented since these provide important insights in the unique and idiosyncratic nature of individual projects. However, these case-oriented researches have little to contribute in terms of patterns recurring in different cases. By their very nature, both types of studies thus have their merits and demerits. Table 1 provides an illustrative list, excluding the above mentioned references by Flyvbjerg *et al.*, of transportation infrastructure development studies that fit the above distinction.

Variable-oriented	Focus on generic patterns	Hecht & Niemeier (2002); Hsieh *et al.* (2004); Irfan *et al.* (2011); Kaliba *et al.* (2009); Lee (2008); Magnussen & Olsson (2006); Manavazhi & Adhikari (2002); Odeck (2004); Polydoropoulou & Roumboutsos (2009); Welde & Odeck (2011); Yang (2007).
Case-oriented	More attention to idiosyncratic events	Anguera (2006); Cantarelli *et al.* (2010); Han *et al.* (2009); Peters (2010); Priemus (2007); Rigden (1983); Van Marrewijk *et al.* (2008); Walter & Scholz (2007).

Table 1 *Variable- And Case-Oriented Studies In Transport Infrastructure Development*

Understanding Complex Infrastructure Projects

If projects are called complex it usually means that they are perceived as difficult. However, the word 'complex' is in fact a multi-layered concept that needs further elaboration. In abstract terms, developing infrastructure means performing modifications to an existing system. Any built area is a system because it consists of interacting three-dimensional units (e.g., rooms, buildings, assemblages of buildings), two dimensional units (i.e., the layout or distribution of the three-dimensional units), and linear units or transport networks linking the three-dimensional units thereby largely determining the area's layout. Together, these form an urban syntax that is specific to any given area (Marshall, 2009). While there are some things that are often in common in many areas (e.g., where the main railway station is located in relation to the town center), there are also many differences that are particular to any local situation (De Roo & Schwartz, 2001). An infrastructure developer wishing to change something to a specific situation, therefore, deals with an urban syntax that is a mixture of generic elements (i.e., elements that also appear elsewhere) and specific elements (i.e., elements that only appear in this local situation). Over time, the interaction of generic elements with specific elements leads to a local situation that is unique in its particularity, even though it still has recognizable elements (Byrne, 1998, 2001, 2003, 2005; Marshall, 2009). The complexity of a built area is further increased if one takes into account that there exists social tissue, i.e., individuals and social groups living, working, traveling and recreating in any given area. The urban syntax and its social components are nested in the way that properties of the subunit (e.g., a street) reflect the properties of the whole (e.g., a district) but not to the extent that both levels are exact copies (Marshall, 2009). Thus, the built order that exists locally is emerging from the specific local conditions. As a consequence, infrastructure developers have to deal with a unique local area that nonetheless exhibits similarities with other areas. Developing infrastructure and built areas is, therefore, not a matter of applying generic planning or managerial rules to that area, because such application would miss out the specific local conditions. It is pivotal for the development of infrastructures in built areas that this specific pattern of local conditions and generic developments is researched and understood. Indeed, these local conditions often play a significant role in the development of infrastructures. For instance, certain ground conditions, residential areas or nature areas affect the development and outcomes of projects.

In sum, this perspective on the development of built areas focuses on a number of dimensions. First, transportation infrastructure development takes place within a specific interacting mix of local conditions (e.g., difficult ground conditions) and generic patterns (e.g., economic crisis) that occurs in any given location. Second, this points to the fact that the causal relationships between site-specific conditions and generic developments and the elements within are poorly known and, if known, only for that specific time and place. Thus, known causal relationships specific to a certain area are by definition case-specific. Indeed, the unique nature of built systems implies that other systems are constituted differently, although the emerged order can be quite similar. Third, the emergent nature of any built area implies that it is the result of longitudinal development. That is, it is the result of past changes and events that are to some extent path-dependent. Taking these points together, this paper understands built areas as complex systems (Batty, 2010). The next question then is: how should this complexity as such be named, understood and researched? This triple question is answered in the following section, leading to the formulation of requisites for complexity-informed evaluation.

Foundations for Understanding and Researching Situated Complexity

There are two basic ways of how complexity can be characterized. Byrne (2005) and Cilliers (2001), among others, make a distinction between simplistic or generic versus complex or situated complexity. Generic complexity focuses on the emergence of complex processes and structures from a limited set of variables. It assumes a general set of rules from which emergent complexity flows (Buijs *et al.*, 2009). Although elegant, this approach does not do justice to the types of project evaluation for which this methodology is being developed. Built areas as systems are open by definition (De Roo, 2010), meaning that their composition and behavior is constituted through interaction with their environment, resulting, as stated above, in their specific local (i.e., situated) mixture of generic and specific elements. So, any approach to understanding them requires that they are treated as such, which implies a situated complexity approach (Gerrits, 2011). The premise of built areas as open systems assumes that an explanation for the development (or lack thereof) of a project can be found in its contextuality, i.e., that the local conditions hold explanatory variables (cf. Mjøset, 2009). Therefore, Buijs *et al.* (2009) use the denominator 'situated complexity' to focus on the explanatory value of the contextuality of a phenomenon. Although some argue that a research methodology should start from either the generic or situated approach (e.g., Bar-Yam, 1997), Buijs *et al.* (2009) argue that a case can and should be made for a systematic in-depth comparison across systems. The idea behind this is that (open) systems "do not operate according to general rules applied in all contexts" (2009: 37), but that nevertheless a systematic comparison can reveal both differences and similarities between the operations of different systems. Situated complexity focuses on both recurring patterns over multiple systems and idiosyncratic events that are local to a particular system, that both determine how systems develop over time. The research methodology presented in this paper starts from that premise.

The second part of the triple question concerns the way complexity is understood, which is basically a question of how reality can be understood. The classical divide is between positivism and postpositivism. To some extent, this divide coincides with the difference between generic and situated complexity. Positivism is primarily concerned with determining general rules in reality by taking it apart in discrete components, which coincides with the aims of the research program into general complexity. However, postpositivism has many different sub-strands that range from the extreme relativism of social constructivism to the more realist thesis of negotiated subjectivism (Byrne, 2003; Haynes, 2001; Uprichard & Byrne, 2006) or critical realism (Guba & Lincoln, 1989). The common theme within those strands is that the contextuality is explanatory for what is being observed, which coincides with situated complexity.

The fact-value dichotomy that underlies the positivist stance has been thoroughly undermined (Bateson, 1984; Byrne, 2002; Fischer & Forester, 1987; 1993). Complex causality is always subject to interpretation and consequently debatable as every interpretation carries with it normative judgments (Williams, 2009). If it is accepted that systems are open, than it follows that systems' boundaries do not exist a priori but that any individual will develop a particular demarcation or set of boundary judgments about the system which includes and excludes variables (i.e., reducing real complexity) that may be connected but not perceived as such by the observer (Cilliers, 2001). In other words, there is no unambiguous separation between systems and their context. Situated complexity is therefore not confined to presupposed systems' demarcations but intersects all system representations by respondents. In other words, the observer is as much part of the complexity as the system or agents that are observed. This reduction of the real complexity is both compromising the research and inevitable in keeping it manageable (Cilliers, 2001, 2005). It requires that multiple perspectives on a particular system are taken into account. If a multitude of observers can develop a multitude of boundary judgments about what is taken into account or not with a multitude of perspectives about how something is being perceived, chances are that a larger part of the complexity of the system is captured (Cilliers, 1998, 2005). This type of thinking implies a convergence of the fact-value dichotomy. However, it does not imply that the postmodernist stance, where subjective storytelling is all that remains, is carried over in this position. It means that it is understood that explanation is possible, as long as it is accepted that it is local in time and place (Byrne, 2001, 2003, 2005; Morçöl, 2001). Although specific to a given locality, cause and effect relations do exist and can be known through respondents' perception (i.e., it is agent-bound). Causality can still be determined in terms of change and response that render certain effects that can be observed (cf. Bryman, 2004; Hammersley, 2008, 2009). The ontological point of departure in this paper is therefore complex realism (cf. Byrne, 2002; Harvey, 2009; Reed & Harvey, 1992).

So, how should this complexity be researched? As situated complexity from the perspective of complex realism is the point of departure in this paper, the adherent methodology should focus on both recurring patterns over multiple systems and on system's peculiarities. Therefore, the first criterion for a complexity-informed evaluation framework is [1] the extent to which it manages to balance between in-depth understanding and reductionist generalization. Second, since studying situated complexity requires first an in-depth understanding of cases, [2] the method has to be case-based. Moreover, since single case studies cannot be employed for explanatory purposes in other cases and, therefore, do not allow statements about patterns across systems, a comparative multiple-case study approach is required. Third, as stated above, situated complexity focuses on the explanatory value of contextuality. Indeed, complex systems are open systems; generic patterns and specific events interact and coevolve. Therefore, it can be inferred that, in methodological terms, [3] the method should allow observation and analysis of complex interaction between variables. This is elaborated in the following sections. Finally, as argued above, since complex systems are anything but static (i.e., a built area is the result of longitudinal development), [4] the method has to be able to account for the influence of time on the constitution of situated complexity (i.e., complex dynamics).

Towards a Complexity Informed Case-Comparative Framework

The requisites mentioned in the previous section are covered only partially by the two general evaluation approaches presented before. Variable-oriented studies such as those performed by Flyvbjerg *et al.* (2003a) examine relationships between more general features of infrastructure projects. These features are conceived as variables (e.g., project type, topography and cost overrun) and the correlations between them are tested. Hereby, it is possible to deduce empirical generalizations about structural processes, relevant to a larger number of cases (Ragin, 1987). For instance, cost underestimation and overrun are higher in rail projects and within the set of rail projects, overrun in developing nations is more pronounced than in North America and Europe (Flyvbjerg, 2007a). "However, the simplifying assumptions that make this approach possible often violate commonsense notions of causation and sometimes pose serious obstacles to making interpretative statements about specific cases or even about categories of cases" (Ragin, 1987: xiii). That is, the study cannot account for the idiosyncratic nature of specific cases, as the study of Anguera (2006) can. Thus, variable-oriented studies are by their very nature not case-oriented. Furthermore, correlational methods are not equipped to deal with contextuality; correlational methods do not allow for complex causality. For example, in the research performed by Flyvbjerg *et al.*, the importance of the context is recognized by pointing to the fact that cost overruns are due to different circumstances (cf. citation in second section). However, this is not reflected in the generic patterns that appear in the research. Finally, variable-oriented studies can account for time. For instance, Flyvbjerg *et al.* (2003a) conclude that infrastructure development performance has not improved in the past 70 years. However, such studies have a hard time including complex dynamics, such as the influence of particular events (e.g., the crash at Lockerbie) on the course of developments in a specific case.

Case-based methods, however, are by their nature sensitive to the complexity, diversity and (historical) uniqueness of cases (Ragin, 1987). Projects are treated holistically and not as collections of parts; case studies are sensitive to contextuality and temporality. For instance, Anguera (2006) is able to discuss in detail the Channel Tunnel project, its performance, and the influential factors thereon just because of the focus on a single case study (see Section 2). However, in the words of Aus, "most case studies (...) could maliciously be qualified as theoretical 'data dumps'. One of the methodological reasons for this rather unfortunate state-of-the-art is that single case studies can hardly be employed for explanatory purposes" (2009: 175). Hence, the methodology needs to be case-comparative to allow for causal inference (Aus, 2009), for studying patterns across cases. However, when case study material is analyzed and compared in case-comparative studies, this often happens rather loosely and non-formalized (Rihoux, 2006). Often, comparative studies, necessarily limited in the number of cases, result in an overview of the most important similarities and differences. This comparative process is often not formalized in the sense that little insight is and can be provided into the way it was performed, including decisions that were made influencing the outcome of the comparative process. The rich data represents many possible causal conditions that are often hard to disentangle and there is a danger of introducing possible biases. Consequently, the scientific value of these studies is often questioned (Ragin, 1987). As Table 2 below summarizes, both approaches have their strengths and weaknesses.

Requirements	Both in-depth and generalization	Both comparative and case-based	Contextuality	Temporal
Variable-oriented	Generic patterns	Comparative, not case-based	At most limited	At most limited
Case-oriented	In-depth case peculiarities	Not comparative, case-based	Yes	Yes

Table 2 *Variable-Oriented Versus Case-Oriented Approach*

In the next section we discuss fsQCA as a hybrid third research approach that aims to integrate the strengths of both the above approaches, thereby mitigating their weaknesses.

QUALITATIVE COMPARATIVE ANALYSIS AND FUZZY SETS

Qualitative Comparative Analysis (QCA)—an umbrella term that captures three different types of comparative methods (Rihoux & Ragin, 2009), namely crisp set QCA (csQCA) (Rihoux & De Meur, 2009), multi-value QCA (mvQCA) (Cronqvist & Berg-Schlosser, 2009) and fuzzy set QCA (Ragin, 2009)—aims to integrate the case-oriented and variable-oriented approaches and argues that scientists do not have to choose between the "understanding of complexity and knowledge of generality" (Ragin *et al.*, 2003: 324). QCA can be used to "achieve a systematic comparison across a smaller number of individual cases (e.g., a sample of between 10 and 30 cases) in order to preserve complexity, and yet being as parsimonious as possible and illuminating otherwise often hidden causal paths on a micro level" (Rihoux & Lobe, 2009: 228). It is a comparative case-based approach that allows for the examination of multiple causal configurations (Byrne, 2009). This configurational approach implies first that most often *combinations* of causal conditions (i.e., variables) produce a certain outcome. For instance, Anguera (2006) presents several factors that together affected cost overrun in the Channel Tunnel project. Second, it implies that several *different combinations* may produce the outcome. For instance, the Øresund link and the Channel Tunnel have similar outcomes, but their paths towards that outcome are different. Third, it implies that certain factors can have different effects in *different contexts*. For instance, the effects of the advent of low cost airlines differ between the Channel Tunnel and the Øresund link due to their different contexts and natures. Grofman & Schneider (2009) and Schneider & Wagemann (2010) refer to these characteristics of complex causality as respectively conjunctural causation, equifinality and multifinality. They add to this the notion of asymmetric causality, i.e., that the presence and absence of outcomes require different explanations. In sum, the approach ticks all of the boxes in Table 2, excluding, as discussed later, the last one concerning temporality.

It is important to clarify that QCA is not just a method; it is first of all a research approach (Rihoux, 2003). Central to this approach is the dialogue between theoretical ideas and empirical evidence (Berg-Schlosser & De Meur, 2009; Berg-Schlosser *et al.*, 2009; Ragin, 1987, 2000, 2008a; Yamasaki & Rihoux, 2009). In our view this means that this research approach is neither purely inductive nor deductive, but essentially a two-way-street whereby (inductive) case-based empirical data is ordered with the help of theory for the selection and construction of cases and variables. In QCA, variables are reframed as causal conditions or sets. Set theory is a "mathematical calculus for dealing with collections of objects and certain relationships among these objects. At its most basic, a set is simply a list of objects" (Smithson & Verkuilen, 2006: 4). For instance, the cases Channel Tunnel, Øresund link and Great Belt link, are all members of the set 'transportation infrastructure projects'. What makes set theory interesting for case comparative studies is that sets can be intersected (i.e., the set operator 'logical and'—referring to conjunctural causation) and unified (i.e., the set operator 'logical or'—referring to equifinality and multifinality). QCA is able to systematically compare and analyze these conjunctions of sets (i.e., variables in different contexts, also known as causal recipes) (Ragin, 1987, 2000, 2008a; Smithson & Verkuilen, 2006). Thus, contextuality is deemed as explanatory for case outcomes. However, social phenomena such as infrastructure development are often difficult to grasp in terms of sets. For instance, consider defining set boundaries of concepts such as 'democracy' and 'legitimacy' as opposed to defining the set of 'transport modes'. Producing a list of projects that fit a certain type of transport mode is probably easier than making a list of legitimate public participation processes in infrastructure development projects (cf. Smithson & Verkuilen, 2006). Therefore, it is important to use theoretical and substantive knowledge to substantiate the construction of sets.

Using set theory implies a focus on set relations instead of correlations. That is, instead of studying the net-additive effects of variables, QCA studies the necessity and sufficiency of relations between (combinations of) sets and the outcome condition (Ragin, 1987, 1999, 2000, 2008a, 2008b; Schneider & Wagemann, 2010). A condition is necessary if it has to be present for the outcome to occur, indicated by the outcome being a subset of the causal condition. Suppose condition B is the set 'cost overrun' and condition A is the set 'construction delay'. Then, Figure 1 shows that every case that exhibits cost overrun (i.e., is in set B) also exhibits construction delay. If a case does not exhibit A, then it cannot be in set B. Thus, according to this figure, construction delay is a necessary condition for the outcome to occur. A condition is sufficient if it can produce the outcome by itself, indicated by the condition being a subset of the outcome. Now suppose that B is the set 'construction delay' and A is 'cost overrun'. Then, Figure 1 shows that every case that exhibits construction delay (i.e., is in set B) also exhibits cost overrun. If construction delay is the only condition at play, then this figure indicates that it alone is sufficient to produce cost overrun. However, as explained by Ragin (2000), necessary and sufficient conditions can and most often are combined within a causal recipe since causation is complex. This means that often there are no pure necessary or sufficient conditions for an outcome to occur. Nevertheless, conditions can be necessary in certain contexts (i.e., configurations). Such conditions

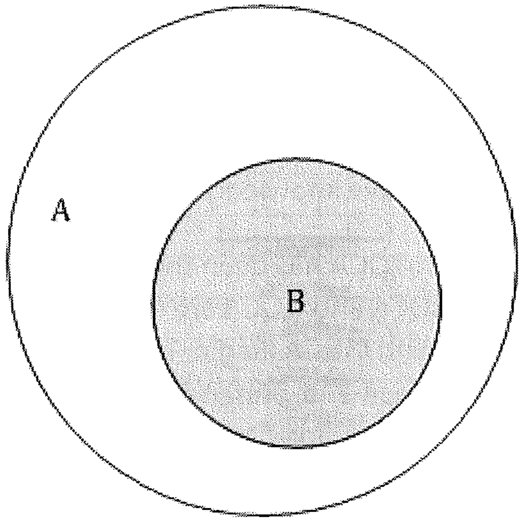

Figure 1 *Set Relations*

are called INUS conditions, which can be defined as an "*insufficient* but *non-redundant* part of an *unnecessary* but *sufficient* condition (Mackie, 1980: 62, original italics). For example, imagine that the Channel Tunnel, Great Belt link and Øresund link have different 'scores' on three causal conditions A, B and C. Suppose that the Channel Tunnel exhibits conditions A and B, the Great Belt link conditions B and C and the Øresund link conditions A and C. Thus, there are three intersected sets: A*B, B*C and A*C. The * sign indicates 'logical and'. These three different 'paths produce the outcome cost overrun. This implies 'logical or', indicated by a + sign. This can be written as a Boolean expression, namely:

$$A*B + B*C + A*C \rightarrow \text{cost overrun}$$

Thus, A and B, or B and C, or A and C result in cost overrun. This means first that none of the three conditions is individually sufficient since in none of the three cases the outcome is produced by a single condition. Second, it means that none of the three conditions is necessary. For instance, condition A is not necessary for cost overrun to appear, since it can also appear in the combination B*C. It does mean, however, that A is an INUS condition: it is a not sufficient (i.e., it cannot produce the outcome by itself) but a non-redundant (i.e., it is a necessary condition in both the combinations A*B and A*C) part of an unnecessary (i.e., A*B and A*C are not necessary since cost overrun also appears in B*C) but sufficient (i.e., A*B and A*C are sufficient for cost overrun to occur) condition. Finally, it is important to note that "neither necessity nor sufficiency exists independently of theories that propose causes" (Ragin, 2008b: 42), because this distinction is only meaningful in the context of theoretical perspectives. In other words, the contextuality of the research method is confined to the included sets, whose construction is substantiated with theoretical and substantive knowledge.

A recent development in QCA has been the introduction of fsQCA (Ragin, 2000; 2008a). Although csQCA and fsQCA are equal in their set-theoretic and configurational rationale, with csQCA (Ragin, 1987) a dichotomous distinction is made between the absence and presence of causal conditions in a case whereas fsQCA allows for finer gradients in degree of set membership (i.e., a variable does not need to be fully present or absent in a case) (cf. Ragin, 2000; 2008a; 2009) and therefore is a more accurate descriptor of the complexity exhibited by infrastructure projects. For instance, with csQCA, an infrastructure project can be fully in or fully out the set 'cost overrun' (i.e., it can score 0 or 1). However, one might argue that a cost overrun of 70 percent in the Øresund link project is substantially different from a cost overrun of 110 percent in the Great Belt project (see Flyvbjerg *et al.*, 2003a). Therefore, the latter may be more in the set 'cost overrun' then the former. This can be formalized by assigning different set memberships to these cases for cost overrun (e.g., 1.0 for the Great Belt project and 0.75 for the Øresund project). Consequently, the set 'cost overrun' constitutes a difference in kind.

When each case is assigned fuzzy set membership scores on each of the conditions, the researcher can move beyond mere theoretical (i.e., set construction) and empirical (i.e., case scoring) description to comparative analysis. The first step is the construction of the truth table. The fundamental unit of analysis is the truth table row (Ragin, 1999). Each row presents a unique theoretical combination of variables (i.e., a configuration of intersected sets). A truth table, then, lists al the logically possible combinations of causal conditions—expressed by the exponential formula 2^k ('k' being the number of conditions) since a condition can be both present and absent—and sorts the cases according to these conditions (i.e., assessing the empirical presence of the combinations). Next, for each causal recipe the outcome value is defined. For illustrative purposes, a hypothetical truth table with three conditions is depicted below. Note that this truth table shows hypothetical dichotomized crisp set data. Due to limited space available, this chapter does not allow for elaborating on the procedures for transforming fuzzy set data to crisp set data.

Condition A	Condition B	Condition C	Outcome	Distribution of cases
1	1	1	1	
1	1	0	1	
1	0	1	1	
1	0	0	1	
0	1	1	1	
0	1	0	0	
0	0	1	0	
0	0	0	0	

Table 3 *Hypothetical Truth Table*

These procedures and their rationale and advantages compared to a crisp set approach are discussed in Ragin (2008a: 124-144).

Note that the process described so far takes the researcher from (inductive) qualitative thick-case descriptions via the construction of sets and the assignment of set membership scores towards the construction of the truth table, thereby completing the inductive-deductive circle. One might argue that this discounts the unique and complex nature of cases. However, it actually formalizes the comparative procedures thereby providing insights therein. This increases the repeatability of case-oriented comparative research. Evaluators or researchers still need to make simplifying choices but these are made visible through the different steps in the QCA research approach. Thus, importantly, the method takes the researcher from in-depth understanding of complex systems to the identification of recurring patterns over multiple systems, without undermining the essence of complex systems: their contextuality and complex causation.

Next, the truth table can be minimized to produce a so-called 'solution' (i.e., a statement about generic patterns across the cases). That is, maximum complexity was assumed a priori, and this complexity is now brought back to its core. This minimization process is structured by using Boolean algebra. Its basic procedure can be summarized as follows: "if two Boolean expressions differ in only one causal condition yet produce the same outcome, then the causal condition that distinguishes the two expressions can be considered irrelevant and can be removed to create a simpler, combined expression" (Ragin, 1987:93). For example, the previous hypothetical truth table gives the following Boolean expressions:

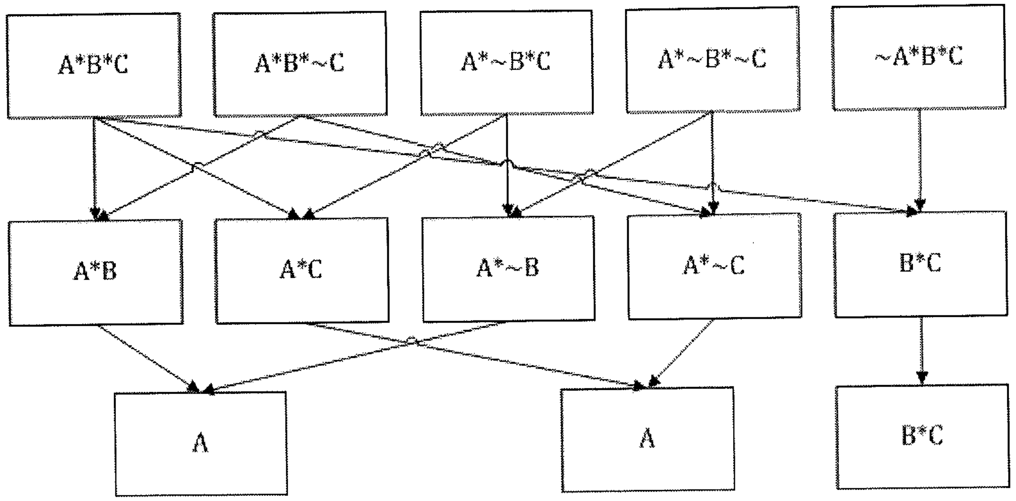

Figure 2 *Boolean Minimization*

A*B*C + A*B*~C + A*~B*C + A*~B*~C + ~A*B*C → cost overrun

The tilde sign (~) indicates the absence of a condition. This expression exhibits five empirically observed paths towards cost overrun. As a next step it can be evaluated what the sufficient, necessary and/or INUS conditions are in this expression. The first two expressions can be minimized to A*B: whether condition C is present or not, cost overrun appears nonetheless. This minimization procedure is displayed in Figure 2 and results in the following solution formula:

A + B*C → cost overrun

It is pivotal that the resulting formula is not applied mechanically in concluding the comparative analysis. As stated above, QCA is first of all a case-based qualitative approach. Hence, the solutions formula should be interpreted in light of the individual cases: does it make sense? In conclusion, this section aimed to provide some insights in the rationale and procedures of fsQCA. Obviously, it is worth discussing many more—such as limited diversity/logical remainders, counterfactual analysis and the measures consistency and coverage—but unfortunately this is not possible due to the limited space available.

DISCUSSION

This paper set out to identify an evaluative framework that would address the complexity of developing transportation infrastructure projects, thereby contributing to the discussion of complexity in evaluation (cf. Callaghan, 2008) and of QCA in evaluation (cf. Befani *et al.*, 2007; Marx, 2005). It was found that the contextuality of such projects is explanatory for the outcomes and that a suitable framework would need to address this contextuality. Some prerequisites were developed and it followed that an ideal type evaluation framework integrates the depth of case-based approaches with the possibilities to generalize using variable-based approaches. This ideal type was found in QCA, specifically fsQCA. Some may argue that it is too much of a compromise, but as a framework it maintains the integrity of the conceptualization of infrastructure development presented in this paper.

While fsQCA fulfills three of the four requisites, it should be acknowledged that it does less well on the fourth, i.e., the time dimension. In essence, the method is static (Rihoux, 2003) and therefore does not capture the dynamics of complex systems to their full extent (cf. Gerrits, 2011). Some provisional workarounds are put forward by, among others, Rihoux (2003) and De Meur *et al.* (2009), for instance by capturing the time dimension by repetitive deployment of the method, by interpreting the time dimension, by conceptualizing time as (part of) a set, or by complementing QCA with other methods. Also, attempts are being made to develop a distinct type of QCA (Caren & Panofsky, 2005). However, all options are compromises and it should be concluded that, while fsQCA is strong in mapping the systemic complexity of infrastructure development, it performs weak on time dynamics.

The approach helps bringing together the generalizations that could be derived from systemic comparison and the in-depth idiosyncratic nature of single systemic cases (cf. Buijs *et al.*, 2009). It follows that this approach is limited in the number of conditions that can be taken into account, since the logically possible number of combinations increases exponentially. It also follows that the addition of a new case to the (restricted) set of cases being compared could lead to different outcomes. Although both issues are not unique to QCA—one could argue that such limitations are inherent to research into social reality—they should not be ignored. Regarding the limited number of conditions being considered, Rihoux (2003) and De Meur *et al.* (2009) suggest that a possible remedy is to carry out multiple routines, i.e., building an increasingly clearer set of conditions by going through the process multiple times. In this way, the researcher is able to find out, in a very transparent way (Rihoux *et al.*, 2009), what conditions do not matter or to find conditions that yield the same or similar results. These conditions can then be excluded from the analysis respectively grouped together in macro variables. Another promising approach is provided by Schneider & Wagemann (2006) who propose to analyze remote (i.e., contextual) and proximate factors separately in a first stage. In a second stage, influential remote and proximate factors are brought together in a single analysis. The second issue, the possibility of arriving at different conclusions after adding new cases, is actually part of the philosophy behind QCA and its roots in systemic thinking. Rihoux (2003) states that with small-n studies, the researcher does not strive to identify a single central tendency that could get closer to reality the more cases are added. Rather, it helps focusing on different causal pathways to an outcome and how such pathways are linked to individual cases. Adding a new case may lead to the discovery of a new pathway. More common comparisons are aimed at finding the variable that controls for differences and similarities in multiple cases. Following the discussion on generic and situated complexity, such a search is beside the point. Every case has its unique pathway and comparison should be used to highlight the particularities of the pathways. Note that QCA moves back and forth between generic and situated complexity. It is also through this perspective that thinking in terms of dependent or independent variables is replaced by thinking of variables as conjunctions (Aus, 2009), which bears a closer resemblance to social reality.

Summarizing the argument in this paper, it can be concluded that fsQCA is a promising approach that largely meets the evaluation requirements set in this paper. Some issues will have to be dealt with, most prominently the time dimension. A next step would be to use fsQCA in a concrete evaluation research to test how it performs when analyzing complex infrastructure development projects.

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