

# Glossary for Configurational Comparative Methods

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## Usage of this document:

In this glossary, internal links to entries have a **red font color**, links to cited publications have a **green font color**, and links to websites or e-mail addresses have a **blue font color**. The hand symbol, , indicates that the respective entry is an acronym, a (close) synonym, or a concept with a meaning equivalent to the entry towards which it points.

## Additional note:

This glossary is a living document. If you have typos or errors to report, suggestions for improvement or other comments that should be considered for a future update, please contact [Alrik Thiem](#).

## Special Symbols

$\neg$	☞	Boolean Inverse
$+$	☞	Boolean Sum
$\cdot$	☞	Boolean Product
$\neg$	☞	Negation
$\vee$	☞	Disjunction
$\wedge$	☞	Conjunction
$\Rightarrow$	☞	Implication (also “ $\rightarrow$ ”)
$\Leftrightarrow$	☞	Equivalence (also “ $\leftrightarrow$ ”)
F	☞	FALSE
T	☞	TRUE
—	☞	Complement
$\cup$	☞	Union
$\cap$	☞	Intersection
$\subset$	☞	Subset (including “ $\subseteq$ ”)
$\supset$	☞	Superset (including “ $\supseteq$ ”)
$\emptyset$	☞	Empty Set
U	☞	Universal Set

## A

Algebra of Sets of Points ☞ Set Theory

Algebra of Switches ☞ Switching Circuit Theory

**Ambiguity** also *causal ambiguity* or *model ambiguity*; the fact of a **solution** in **QCA** and **CNA** consisting of multiple **models** that fare equally well in accounting for the analyzed set of **configurational data**; see also *Determinacy*; for more details, see Baumgartner and Thiem (2015b)

**Anchor** also *calibration anchor*; a **set membership score** to which a **threshold** is pegged for the purpose of performing **calibration** by means of **assignment by transformation**;

important anchors are 0, 0.5 and 1

**Antecedent** the expression on the left hand-side of an **implication** or **equivalence**; e.g.: in  $(A \vee B \Rightarrow C)$ ,  $A \vee B$  is the antecedent; see also *Consequent*

**Assignment by Transformation** a technique of **calibration**; the process of mapping a **base variable** onto a scale of **set membership** by some mixture of theoretical and empirical **assignment criteria**; for more details, see Verkuilen (2005)

**Assignment Criterion** the rule whereby the values of the **base variable** are mapped onto a scale of **set membership**; a theoretical criterion uses knowledge external to the data; an empirical criterion uses knowledge internal to the data

**Associativity** a binary **Boolean operator** “ $\star$ ” is associative if, and only if, it holds that

$$(a \star b) \star c = a \star (b \star c);$$

the fundamental **Boolean operators** “ $+$ ” and “ $\cdot$ ” are associative because it holds that  $(a + b) + c = a + (b + c)$  and  $(a \cdot b) \cdot c = a \cdot (b \cdot c)$

**Atomic Solution Formula** a **CNA** term; an **implication** or **equivalence** with an **antecedent** consisting of a **minimally necessary disjunction** of **minimally sufficient conditions** in **disjunctive normal form** and with a **consequent** consisting of one **outcome**

## B

**Background Assumption** an assumption about the quality of analyzed data that must be satisfied in order for a **procedure of causal inference**  $\mathcal{P}$  to be **correct** and **complete**; all **procedures of causal inference**, including **QCA** and **CNA**, require background assumptions; see Cartwright (1989)

**Background Condition** also *ceteris paribus condition*, one of the set of constants within the **causal field**  $\mathcal{F}$  under which a causal dependency holds

**Base Variable** the variable to be mapped onto a scale of **set membership** by means of **calibration**; see also *Assignment by Transformation*, *Direct Assignment* and *Indirect Assignment*

**Boolean Algebra** a set of elements with two binary operators, “ $+$ ” and “ $\cdot$ ”, such that  $+$  and  $\cdot$  are closed,  $+$  and  $\cdot$  are **commutative**,  $+$  and  $\cdot$  are **distributive** over each other,  $+$  has a unit element 0 (**identity**),  $\cdot$  has a unit element 1 (**identity**), and for every element  $a$  there is an element  $a'$  such that  $a + a' = 1$  and  $a \cdot a' = 0$  (**complementarity**); for more details, see Hohn (1966) and Thiem, Baumgartner and Bol (2016, 745-752)

**Boolean Inverse** a unary **Boolean-algebraic operation** having “ $'$ ” as its main operator; e.g.:  $(a')' = a$

**Boolean Operator** a function that maps elements of a **Boolean algebra** onto elements of that same algebra; a unary operator maps a single element  $a$  onto another element

$b$ , a binary operator maps an ordered pair of elements  $\langle a, b \rangle$  onto a third element  $c$ ; fundamental Boolean operators are the unary operator “'”, and the two binary operators “+” and “ $\cdot$ ”; by means of the fundamental operators any number of non-fundamental operators such as “ $\Rightarrow$ ” or “ $\Leftrightarrow$ ” can be defined

**Boolean Operation** the execution of a **Boolean operator**

**Boolean Product** a binary **Boolean-algebraic operation** having “ $\cdot$ ” as its main operator; e.g.:  $a \cdot b$

**Boolean Sum** a binary **Boolean-algebraic operation** having “+” as its main operator; e.g.:  $a + b$

**Breakdown** a situation in which not a single **minterm** in the **truth table** meets the **inclusion cut-off**

**Brute-Force Method**  **Exhaustive Enumeration**

## C

**Calibration** the process of assigning objects to **sets** of analytical interest to a certain degree, called **set membership score**; usually carried out by **direct assignment**, **indirect assignment** or **assignment by transformation**; see also *Assignment Criterion* and *Membership Function*; for more details, see Verkuilen (2005)

**Calibration Anchor**  **Anchor**

**Calibration Threshold**  **Threshold**

**Canonical Product**  **Minterm**

**Canonical Sum** a sum of **canonical products**

**Case** a unit of observation instantiating a **configuration**

**Causal Ambiguity**  **Ambiguity**

**Causal Chain**  **Causal Chain Structure**

**Causal Chain Structure** also *causal chain*; informally: a causal structure in which at least one **condition** and/or its **negation** is a cause and an effect at the same time; formally: a **conjunction** of two (or more) **atomic solution formulae** in which at least one **condition** or its **negation** appears in the **antecedent** of one **atomic solution formula** and in the **consequent** of another such formula; e.g.:  $(A \vee B \Rightarrow C) \wedge (C \vee D \vee E \Rightarrow F)$

**Causal Field** the set of unmeasured **background conditions**  $\mathcal{F}$  in conjunction with which a causal dependency holds; e.g.: the gravitational force of the earth constitutes part of the field in which a causal dependency between the throw of a stone at a window and the

shattering of this window holds

**Causal Ordering** an optional argument in **CNA** which takes a sequence of all **factors**  $\langle A_1, \dots, A_n \rangle$  in the **factor frame** as input and excludes that  $A_j$  is a cause of any of its predecessors  $A_1$  to  $A_i$ , for  $i < j$

**Causal Fallacy** an **incorrect** causal conclusion drawn by a **procedure of causal inference**  $\mathcal{P}$

**Causal Path**  $\Rightarrow$  **Path**

**CCMs**  $\Rightarrow$  **Configurational Comparative Methods**

**Ceteris Paribus Condition**  $\Rightarrow$  **Background Condition**

**cna** a software package for **CNA** by Mathias Ambuehl, **Michael Baumgartner**, Ruedi Epple, Alexis Kauffmann and **Alrik Thiem**; see **Ambuehl et al. (2015)**; for more details, see **Baumgartner and Thiem (2015a)**

**CNA**  $\Rightarrow$  **Coincidence Analysis**

**Coincidence Analysis** abbr. **CNA**; a member of the family of **CCMs** proposed by **Michael Baumgartner** that does not rely on the **Quine-McCluskey algorithm** but implements a **minimization** algorithm without reliance on **counterfactual configurations** that is custom-built for the analysis of **causal chain** and **common cause structures**; for more details, see **Baumgartner (2009)**

**Combinatorial Computation** a method in **CCM** sensitivity diagnostics whereby changes in the **truth table** are evaluated to analyze the stability of a reference **solution**; see also **Exhaustive Enumeration**; for more details, see **Thiem, Spöhel and Duşa (2016)**

**Common Cause Structure** informally: a causal structure with at least one cause that has two parallel effects; formally: a **conjunction** of two or more **atomic solution formulae** in which at least one **condition** appears in the **antecedents** of two **atomic solution formulae**; e.g.:  $(A \vee B \Rightarrow C) \wedge (A \vee D \vee E \Rightarrow F)$

**Commutativity** a binary **Boolean operator** “ $\star$ ” is commutative if, and only if, it holds that

$$a \star b = b \star a;$$

the fundamental **Boolean operators** “ $+$ ” and “ $\cdot$ ” are commutative because it holds that  $a + b = b + a$  and  $a \cdot b = b \cdot a$

**COMPASSS** abbr. **Comparative Methods for Systematic cross-case Analysis**; an international network of researchers developing and promoting **CCMs** via a resource website at [www.compasss.org](http://www.compasss.org), publications, conferences, workshops, seminars and software development

**Complement** a **set-theoretic** term; denoted by “ $-$ ”;  $\Rightarrow$  **Negation**; the complement  $\overline{A \cup B}$  of  $A \cup B$  is shown in Figure 1:

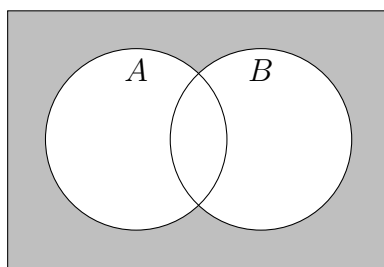


Figure 1: A Venn diagram of the complement  $\overline{A \cup B}$  of  $A \cup B$

**Complementarity** also *laws of complementarity*

**Completeness** a property of a **procedure of causal inference**  $\mathcal{P}$ ;  $\mathcal{P}$  is complete if, and only if, at least one of its output **models** represents all causal relations that are true to the **data-generating structure**, provided that  $\mathcal{P}$ 's **background assumptions** are satisfied

**Complete Product**  $\Rightarrow$  **Minterm**

**Complete Sum** the sum of all **prime implicants** of a Boolean function

**Complex Solution**  $\Rightarrow$  **Conservative Solution**

**Complex Solution Formula** a term in **CNA**; a **conjunction** of two or more **atomic solution formulae** such that every pair of **atomic solution formulae** in that **conjunction** has at least one **factor** in common, but not a common **consequent**; not to be confused with the **complex solution** in **QCA**

**Condition** any (complex **disjunction** of **conjunctions** of) **exogenous factor level(s)**

**Configuration** a **conjunction** of **factor levels** in which each **factor** is represented only once

**Configurational Comparative Methods** abbr. **CCMs**; also *set-theoretic methods*; a collection of methods for the analysis of **configurational data**

**Configurational Confounder** also *confounder*; an unmeasured causally relevant **factor** of an **outcome**  $Z$  for which it holds that when it changes from one level to another a **CCM** is induced to output an **incorrect solution** for  $Z$ , i.e. to commit a **causal fallacy**; the set  $\mathbf{W}(Z, \mathbf{F})$  of confounders of  $Z$  relative to a **factor frame**  $\mathbf{F}$  comprises all causally relevant **factors** of  $Z$  that can change  $Z$  independently of  $\mathbf{F}$

**Configurational Correctness** specification of **correctness** for **CCMs**; a **CCM** is a correct **procedure of causal inference** iff, whenever it infers a set of **models**  $\mathbf{M}$  from a **data set**  $\delta$ , then at least one **model**  $\mathbf{m}_i \in \mathbf{M}$  satisfies the following three constraints: (1) all **conditions** contained in  $\mathbf{m}_i$  are causally relevant in the  $\delta$ -**generating structure**  $\Delta$ ; (2) if two **conditions**  $X$  and  $Y$  are contained in two different **disjuncts** in  $\mathbf{m}_i$ , then  $X$  and  $Y$  are located on two different causal **paths** in  $\Delta$ ; (3) if two **conditions**  $X$  and  $Y$  are contained in the same **conjunct** in  $\mathbf{m}_i$ , then  $X$  and  $Y$  are part of the same complex cause in  $\Delta$

**Configurational Data** data that are **calibrated** and suitable for being analyzed by means

of CCMs

**Configurational Homogeneity** a core background assumption of CCMs: configurational data  $\delta$  for an outcome  $Z$  over a factor frame  $\mathbf{F}$  are homogenous iff every confounder in  $\mathbf{W}(Z, \mathbf{F})$  is present in all cases in  $\delta$  or absent in all cases in  $\delta$ .


**Confounder**  Configurational Confounder

**Conjunct** a term in a conjunction

**Conjunction** a fundamental Boolean operation used in propositional logic that can be translated as “... and ...”; denoted by “ $\wedge$ ”, e.g.  $A \wedge B$ , or alternatively by mere concatenation, i.e.  $AB$ ; conjunction behaves as shown in Table 1:

Table 1: Truth table for conjunction

A	B	$A \wedge B$
0	0	0
0	1	0
1	0	0
1	1	1

**Consequent**  Outcome

**Conservative Solution** also *complex solution*; a solution type in QCA that assumes all remainders in the truth table to be insufficient for the outcome; there is no analogue in CNA; see also *Parsimonious Solution*, *Intermediate Solution*, and *Search Strategy*

**Consistency**  Inclusion

**CONSOL-Effect** an effect described by Alrik Thiem according to which T/ESA, instead of achieving its declared goal of enhancing parsimonious and intermediate solutions, leads to the output of conservative solutions; for more details, see Thiem (2015)

**Contradiction** in propositional logic, a complex proposition that is false under all possible truth value assignments to its component propositions; e.g.:  $A \wedge \neg A$ ; often also used in QCA to denote a minterm which includes at least one case that exhibits the outcome and at least one case that exhibits the negation of this outcome

**Contradictory Simplifying Assumption** in QCA, a remainder that has been used by the Quine-McCluskey algorithm in the generation of the solution for an outcome as well as the negation of this outcome

**Correctness** a property of a procedure of causal inference  $\mathcal{P}$ ;  $\mathcal{P}$  is correct if, and only if, all causal relations represented by at least one of its output models truthfully reflect properties of the data-generating structure, provided that  $\mathcal{P}$ 's background assumptions

are satisfied

**Counterfactual** a **configuration** that has not been observed but is introduced by **QCA** for purposes of **minimization**; see also *Remainder*, *Difficult Counterfactual*, and *Easy Counterfactual*

**Coverage** also *raw coverage*; the degree to which a **proposition** about the **sufficiency/necessity** of an **outcome** for a **condition** is true (value between 0 and 1); see also *Unique Coverage*

**Crisp-Set Qualitative Comparative Analysis** abbr. csQCA; basic variant of the **QCA** family; requires bivalent **exogenous factors**

**Crossover** also (1) *crossover threshold* or (2) *crossover anchor*; in meaning (1), the value from a **base variable** that is pegged to the 0.5-anchor on the scale of **set membership**; in meaning (2), the 0.5-anchor

**Crossover Anchor**  **Crossover**

**Crossover Threshold**  **Crossover**

**csQCA**  **Crisp-Set Qualitative Comparative Analysis**

**Curly-Bracket Notation** a way of denoting simple **conjuncts** mainly used in **mvQCA** and **gsQCA** in which both the **factor** and one or more of its **levels** are combined, e.g.  $A\{1\}$  means that **factor**  $A$  takes on **level** “1”, and  $Z\{\alpha, \beta\}$  means that **factor**  $Z$  takes on **level** “ $\alpha$ ” or level “ $\beta$ ”

## D

**Data**  **Configurational Data**

**Data-Generating Process**  **Data-Generating Structure**

**Data-Generating Structure** also *data-generating process*; the causal structure that generated the analyzed data in reality; the search target of **QCA** and **CNA**

**De Morgan Laws** after nineteenth-century British mathematician Augustus De Morgan; rules to transform a **conjunction** of two **propositions** into their **disjunction** and *vice versa*; together with **involution** also referred to as **laws of complementation**; the De Morgan Laws state the following **equivalencies**:

$$\neg(A \wedge B) \Leftrightarrow \neg A \vee \neg B$$

$$\neg(A \vee B) \Leftrightarrow \neg A \wedge \neg B$$

which behave as shown in Table 2:

**Deduction** one of two major types of inference; the premises of a valid deductive inference necessitate its conclusion, meaning that it is impossible for its premises to be true and its conclusion to be false; the conclusion of a deductive inference is contained in its premises;



Table 2: Truth table for De Morgan laws

A	B	$\neg(A \wedge B)$	$\neg A \vee \neg B$	$\neg(A \vee B)$	$\neg A \wedge \neg B$
0	0	1	1	1	1
0	1	1	1	0	0
1	0	1	1	0	0
1	1	0	0	0	0

a deductive inference extracts information from its premises; e.g., “All swans are white. Therefore, Berni the swan is white”; see also *Induction*, *Demonstrative Induction*

**Demonstrative Induction** a special type of *deductive inference* that features at least one premise that can only be justified via an *inductive inference*; e.g., “Swan 1 is white. Swan 2 is white. Swan 3 is white. Birds have uniform color. Therefore, all swans are white”; causal inferences typically have the form of demonstrative induction

**Determinacy** the fact of a *solution* comprising only a single *model*; see also *Ambiguity*

**Difference-Making** the property of causes by which they can be identified in empirical data: causes are *factors* such that changes in their *levels* can make a difference to the *outcome*; for example,  $Y$  is a difference-maker to  $Z$  in the table below:

Case	Factors										Y	Z
	X <sub>1</sub>	X <sub>2</sub>	X <sub>3</sub>	X <sub>4</sub>	X <sub>5</sub>	X <sub>6</sub>	X <sub>7</sub>	X <sub>8</sub>	X <sub>9</sub>	X <sub>10</sub>		
1	1	0	1	0	1	0	1	0	1	0	1	1
2	1	0	1	0	1	0	1	0	1	0	0	0

**Difficult Counterfactual** in *intermediate solutions*, a *remainder* that has been barred from being used as a *simplifying assumption*

**Direct Assignment** a technique of *calibration*; the process of a human expert mapping an existing *base variable* onto a scale of *set membership* by substantive concerns

**Direct Method of Calibration** a *calibration* procedure introduced by Ragin (2008, 89-94), which uses a specific logistic membership function (*assignment by transformation*); not to be confused with *direct assignment* as a technique of *calibration*

**Disjunct** a term in a *disjunction*

**Disjunction** a fundamental *Boolean operation* used in *propositional logic* that can be translated as “... or ...”; denoted by “ $\vee$ ”, e.g.  $A \vee B$ ; disjunction behaves as shown in Table 3:

**Disjunctive Normal Form** a *disjunction* of one or more *conjunctions* with one or more

Table 3: Truth table for disjunction

A	B	A ∨ B
0	0	0
0	1	1
1	0	1
1	1	1

literals

**Distinguished Column**  **Distinguished Minterm**

**Distinguished Minterm** also *distinguished column*; a **positive minterm** in the **prime implicant chart** that is covered by only one **prime implicant**

**Distributivity** a binary **Boolean operator** “ $\star$ ” is distributive over another binary **Boolean operator** “ $\diamond$ ” if, and only if, it holds that

$$a \star (b \diamond c) = (a \star b) \diamond (a \star c);$$

the fundamental **Boolean operators** “ $+$ ” and “ $\cdot$ ” are distributive over each other because it holds that  $a + (b \cdot c) = (a + b) \cdot (a + c)$  and  $a \cdot (b + c) = (a \cdot b) + (a \cdot c)$

**Don't Care Combination**  **Remainder**

**Duality** also *principle of duality*; any result which is true for a **Boolean algebra** is also true if  $+$  and  $\cdot$  as well as 0 and 1 are interchanged

## E

**Easy Counterfactual** in **intermediate solutions**, a **remainder** that has been used as a **simplifying assumption**

**eQMC**  **Enhanced Quine-McCluskey Algorithm**

**Empty Set** a **set-theoretic** term; a **set** with no elements; denoted by “ $\emptyset$ ”

**Endogenous Factor** an output variable in **QCA** from which the **outcome** is drawn and that can take on at least two **levels**

**Enhanced Quine-McCluskey Algorithm** abbr. *eQMC*; a **minimization** procedure initially implemented in the **QCA** package for the R environment; now in use in the **QCAGUI** package and the **QCApro** package; for more details, see [Duşa and Thiem \(2015\)](#); see also *Quine-McCluskey Algorithm*

**Enhanced Standard Analysis** abbr. *ESA*; a procedure proposed by [Carsten Q. Schnei-](#)

der and Claudius Wagemann for enhancing **parsimonious** and, ultimately, **intermediate solutions** by making certain **remainders** (incoherent counterfactuals and implausible counterfactuals) unavailable to the **Quine-McCluskey algorithm**; for more details, see **Schneider and Wagemann (2013)**; see also *Theory-Guided/Enhanced Standard Analysis*

**Equifinality** a concept accredited to **von Bertalanffy (1950)**; in **QCA**, understood to be the fact of an **outcome** being brought about by different initial conditions along different **paths**; see also *Multifinality*

**Equivalence** denoted by “ $\Leftrightarrow$ ” or “ $\leftrightarrow$ ”; a non-fundamental **Boolean operation** used in **propositional logic** that can be translated as “ $A$  if, and only if,  $B$ ” or “ $A$  is necessary and sufficient for  $B$ ” or “ $B$  is sufficient and necessary for  $A$ ”; defined as  $A \Leftrightarrow B \stackrel{\text{def}}{=} \neg(A \wedge \neg B) \wedge \neg(\neg A \wedge B)$ ; equivalence behaves as shown in Table 4:

Table 4: Truth table for equivalence

A	B	$A \Leftrightarrow B$
0	0	1
0	1	0
1	0	0
1	1	1

**ESA**  **Enhanced Standard Analysis**

**Essential Prime Implicant** also *essential row*; a **prime implicant** covering a **positive minterm** in the **prime implicant chart** that is not covered by any other **prime implicant**  $\rightarrow$  part of each **model** of a **solution**; see also *Inessential Prime Implicant*

**Essential Row**  **Essential Prime Implicant**

**Exhaustive Enumeration** also *brute-force method*; a method in **CCM** sensitivity diagnostics whereby all possible solutions of an analysis are systematically produced and evaluated to analyze the stability of a reference **solution**; see also *Combinatorial Computation*; for more details, see **Thiem, Spöhel and Duşa (2016)**

**Exogenous Factor** an input variable in **QCA** that can take on at least two **levels**

**Extensionality** a principle of classical logic; a **proposition**  $p$  is extensional iff  $p$ 's **truth value** cannot be changed by substituting expressions occurring in  $p$  by other expressions with the same reference; e.g., “Jocasta is the mother of Oedipus” is extensional, but “Oedipus knows that he loves Jocasta” is not

## F

**Factor** a variable with at least two values that is either measured on a nominal or ordinal scale; see also *Endogenous Factor*, *Exogenous Factor*, *Factor Frame* and *Factor Level*

**Factor Frame** the set of all **factors** whose causal interplay is analyzed in a run of **CNA** or **QCA**

**Factor Level** a value that a **factor**, which is either measured on a nominal or ordinal scale, can take on

**FALSE** a **truth value** in **propositional logic**; denoted by “F” and commonly also by “0”

**Frequency Cut-Off** the lower bound below which the number of **cases** within a **minterm** must not fall if this **minterm** is not to be classified as a **remainder**

**fs/QCA** fuzzy-set/Qualitative Comparative Analysis; a **QCA** computer program initially developed by **Charles Ragin**, Sean Davey and Kriss Drass; see **Ragin and Davey (2014)**

**fsQCA**  **Fuzzy-Set Qualitative Comparative Analysis**

**Function Table**  **Truth Table**

**Fundamental Product**  **Minterm**

**fuzzy** the name of an ado-file for **QCA** for the commercial statistics software STATA® developed by **Kyle C. Longest** and **Stephen Vaisey** (currently not maintained any more); see **Longest and Vaisey (2008)**

**Fuzzy-Set Qualitative Comparative Analysis** abbr. fsQCA; a variant of **QCA**, proposed by **Charles Ragin**, which extends **csQCA** by allowing objects to be partial members of **sets**; for more details, see **Ragin (2000, 2008)**

**Fuzzy-Set Theory** a generalization of classical **set theory** initiated by Lofti Zadeh; for more details, see **Zadeh (1965)**

## G

**Generalized-Set Qualitative Comparative Analysis** abbr. gsQCA; a variant of **QCA**, proposed by **Alrik Thiem**, which integrates and extends **fsQCA** and **mvQCA**; see **Thiem (2014b)**

**Graph-Based Agent** the **minimization** algorithm used by **Tosmana**

**gsQCA**  **Generalized-Set Qualitative Comparative Analysis**

## H

**Homogeneity**  **Configurational Homogeneity**

## I

**Idempotency** a theorem in **Boolean algebra** which says that  $a + a = a$  and  $a \cdot a = a$ ; false for linear algebra

**Identity** also *laws of identity*; a theorem in **Boolean algebra** which says that  $a + 0 = a$  and  $a \cdot 1 = a$

**Implicant** a **conjunction** being generated during the **minimization** of **sufficient conditions**; trivially, **minterms** and **prime implicants** are also implicants

**Implication** denoted by “ $\Rightarrow$ ” or “ $\rightarrow$ ”; a non-fundamental **Boolean operation** used in **propositional logic** that can be translated as “if  $A$ , then  $B$ ” or “ $A$  is sufficient for  $B$ ” or “ $B$  is necessary for  $A$ ”; defined as  $A \Rightarrow B \stackrel{\text{def}}{=} \neg(A \wedge \neg B)$ ; also “ $\Leftarrow$ ” and “ $\leftarrow$ ” for “If  $B$ , then  $A$ ” etc.; implication behaves as shown in Table 5:

Table 5: Truth table for implication

A	B	$A \Rightarrow B$
0	0	1
0	1	1
1	0	0
1	1	1

**Inclusion** also *consistency*; the degree, between 0 and 1, to which a **proposition** about the **sufficiency/necessity** of a **condition** for an **outcome** is true

**Inclusion Cut-Off** the lower bound below which the empirical **inclusion** score of a **minterm** that is no **remainder** must not fall if it is to be classified as a **positive minterm**

**Indirect Assignment** a technique of **calibration**; similar to **direct assignment** but experts provide information that is used to map an existing variable onto a scale of **set membership** via a statistical model

**Induction** also *ampliative inference*; one of the two major types of inference; the premises of an inductive inference do not necessitate its conclusion, as the latter states more than is contained in the former; an inductive inference merely aims to increase the probability of its conclusion; e.g., “Swan 1 is white. Swan 2 is white... Swan 1000 is white. Therefore, all swans are white”; see also *Deduction, Demonstrative Induction*


**Inessential Prime Implicant** **prime implicants** that are not part of each **model** of a

solution

**Inference Procedure**  Procedure of Causal Inference

**Informativeness** a property of a procedure of causal inference  $\mathcal{P}$ ;  $\mathcal{P}$  is informative if, and only if,  $\mathcal{P}$  uncovers all and only those causal properties of the  $\delta$ -generating structure for which the processed data  $\delta$  supply empirical evidence; see Spirtes, Glymour and Scheines (2000, 289-291)

**Input Parameter** in sensitivity diagnostics, any parameter that has an impact on the quality of the data to be analyzed by means of a CCM; see also *Throughput Parameter*

**Insufficient Minterm**  Negative Minterm

**Intermediate Solution** a solution type in QCA proposed by Charles C. Ragin and John Sonnett that assumes some remainders in the truth table not to be sufficient for the outcome (difficult counterfactuals); for more details, see Ragin and Sonnett (2005); there is no analogue in CNA; see also *Parsimonious Solution*, *Conservative Solution*, and *Search Strategy*

**Intersection** a set-theoretic operation; denoted by “ $\cap$ ”;  Conjunction; the intersection  $A \cap B$  of two sets  $A$  and  $B$  is shown in Figure 2:

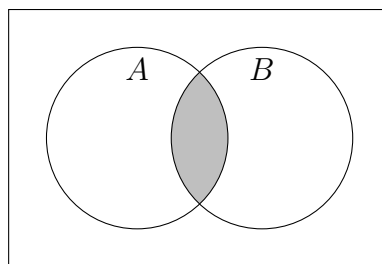


Figure 2: A Venn diagram of the intersection  $A \cap B$  of sets  $A$  and  $B$

**INUS Causality** a successor of John S. Mill’s theory of “chemical causation” developed by John L. Mackie (Mackie, 1974); see also *INUS Condition*

**INUS Cause**  INUS Condition

**INUS Condition** also *INUS cause*; an insufficient but necessary part of a condition which is itself unnecessary but sufficient for the outcome;  $A$  is an INUS condition of an outcome  $P$  if, and only if, for some  $X$  and for some  $Y$ ,  $\mathcal{F} \wedge (A \wedge X \vee Y) \Leftrightarrow P$ , where  $\mathcal{F}$  denotes a causal field,  $A \wedge X$  a minimally sufficient condition of  $P$ , and  $Y$  a disjunction of minimally sufficient conditions of  $P$

**Inverse Search** a design for testing the correctness or completeness of a procedure of causal inference

**Involution** also *law of involution*; a theorem in Boolean algebra which says that  $(a')' = a$

J

K

**Kirq** a **QCA** computer program developed by Christopher Reichert and **Claude Rubinson**; see **Reichert and Rubinson (2014)**

L

**Laws of Complementarity**  **Complementarity**

**Laws of Complementation** collective term for **De Morgan laws** and **involution**

**Law of Excluded Middle** fundamental law of classical logic according to which a **proposition** must be either true or false, i.e. there is no intermediate truth value between truth and falsity; behaves as shown in **Table 6**:

Table 6: Truth table for law of excluded middle

A	$A \vee \neg B$
0	1
1	1

**Laws of Identity**  **Identity**

**Law of Involution**  **Involution**

**Level**  **Factor Level**

**Limited Empirical Diversity**  **Limited Diversity**

**Limited Diversity** also *limited empirical diversity*; the fact of a **truth table** not being **saturated**; the larger the number of **remainders** relative to the dimension of a **truth table**, the higher limited diversity

**Literal** a **level** of an **exogenous** or **endogenous factor**

**Logical Remainder**  **Remainder**

## M

**Membership Function** also *set membership function*; in **calibration**, the (set of) rule(s) that maps the **base variable** onto the scale of **set membership**

**Method of Agreement** first canon of Mill's four methods of experimental inquiry; if two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree is the cause or effect of the given phenomenon; see also *Mill's Methods* and *Method of Difference*

**Method of Difference** second canon of Mill's four methods of experimental inquiry; if an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former; the circumstance in which alone the two instances differ, is the effect, or the cause, or an indispensable part of the cause, of the phenomenon; see also *Mill's Methods* and *Method of Agreement*

**Mill's Methods** a collection of four methods of experimental inquiry (**Method of Agreement**, **Method of Difference**, Method of Residues, Method of Concomitant Variations) introduced in *A System of Logic, Ratiocinative and Inductive* (Mill, 1843); a fifth method, called Joint Method of Agreement and Difference, consists in a double employment of the **Method of Agreement**; see also *Method of Agreement* and *Method of Difference*

**Min-Max Theorem** an object can have a membership score of at most 0.5 in more than one **minterm**, but it can only have membership above 0.5 in a single **minterm**

**Minterm** also *canonical product*, *complete product*, *fundamental product* or *primitive expression*; a minterm of  $k$  **factors** is a **Boolean product** of  $k$  **literals** in which each **factor** appears exactly once, in one of its **levels**

**Minterm Matrix** an essential component of a **truth table** in **QCA**; the set of all unique **Boolean products** of  $k$  **literals** in which each of the  $k$  **exogenous factors** appears exactly once in one of its **levels**

**Minimal Disjunctivity** a **minimization** criterion in the **Quine-McCluskey algorithm** that eliminates **models** with a non-minimal number of **disjuncts**; see also *Minimal Sum Model* and *Row Dominance*

**Minimal Sum Model** a **model** with a minimal number of disjuncts (alternative causes); see also *Minimal Disjunctivity*; an example of a **PI chart** for which there exist two models, but only minimal sum model (model 2), is given in Table 7 below:

**Minimality** the requirement for a Boolean expression to be free of **redundancies** in order to represent a **model**

**Minimally Necessary Condition** in **CNA**, a **disjunction** (with one or more **disjuncts**) that is **necessary** for an **outcome** and cannot be reduced by one or more **disjuncts** such



Table 7: A prime implicant chart with one minimal sum model (model 2)

	1	6	7	10	11	14	15	
PIs	abcD	aBCd	aBCD	AbCd	AbCD	ABCd	ABCD	
A	-	-	-	x	x	x	x	
B	-	x	x	-	-	x	x	
C	-	x	x	x	x	x	x	model 1: $A \vee B \vee D$
D	x	-	x	-	x	-	x	model 2: $C \vee D$

that the remaining **disjunction** is still **necessary** for that **outcome**

**Minimally Sufficient Condition** in **CNA**, a **conjunction** (with one or more **conjuncts**) that is **sufficient** for an **outcome** and cannot be reduced by one or more **conjuncts** such that the remaining **conjunction** is still **sufficient** for that **outcome**; the equivalent of a **prime implicant** in **QCA**

**Minimal Theory** in **CNA**, an **atomic** or **complex solution formula**

**Minimization** also *reduction, optimization* or *simplification*; the process of eliminating redundant **factors** in **CNA** and **QCA** so as to derive the **solution**; see also *Enhanced Quine-McCluskey Algorithm, Graph-Based Agent* and *Quine-McCluskey Algorithm*

**Model** in **QCA**, a minimally necessary **disjunction** of **prime implicants** which represents an element in a **solution**; in **CNA**, an **atomic** or **complex solution formula**; e.g.:  $(\neg A \wedge B) \vee (B \wedge \neg C) \vee D \Leftrightarrow Z$

**Model Ambiguity**  **Ambiguity**

**Monotonicity** the fact that a **factor level** which is part of a **necessary condition** of an **outcome** does not lose this property when further **factor levels** are added by **disjunction**; the fact that a **factor level** which is part of a **sufficient condition** of an **outcome** does not lose this property when further **factor levels** are added by **conjunction**

**Multi-Value Qualitative Comparative Analysis** abbr. mvQCA; a variant of **QCA** proposed by Lasse Cronqvist which extends **csQCA** by permitting the inclusion of multivalent **exogenous factors** in the **factor frame**

**Multifinality** in **QCA**, the notion that some **factor level** is causally relevant to an **outcome** and its **negation**; see also *Equifinality*

**mvQCA**  **Multi-Value Qualitative Comparative Analysis**

## N

**NCA**  **Necessary Condition Analysis**

**Necessary Condition** a **condition** that appears in the **consequent** of a true **implication**

**Necessary Condition Analysis** abbr. NCA; a method proposed by [Jan Dul \(Dul, 2016\)](#), consisting of a collection of optimization techniques for identifying ceiling lines on concentration regions of data

**Necessity** a functional dependency based on Boolean concepts; if  $A$  is necessary for  $B$ , then the **conjunction** of  $\neg A$  and  $B$  is false; see also *Implication*

**Negation** a fundamental **Boolean operation** used in **propositional logic** that can be translated as “not ...”; denoted by “ $\neg$ ”; negation behaves as shown in [Table 8](#) below:

Table 8: Truth table for negation

A	$\neg A$
0	1
1	0

**Negative Minterm** also *insufficient minterm*; in **QCA**, a **minterm** with an **output value** of “0”; see also *Positive Minterm* and *Remainder*

## O

**One-Difference Restriction** a criterion regulating the eliminability of a **factor level** from a **sufficient condition** in **Quine-McCluskey optimization**

**Optimization**  **Minimization**

**Ordering**  **Causal Ordering**

**Orphan Column** a column in a **PI chart** corresponding to a positive **minterm** that is exclusively covered by (multiple) inessential **prime implicants**; see also *Ambiguity*

**Outcome** also *consequent*; the **level** of the **endogenous factor** whose instantiation is sought to be explained

**Output Value** in **QCA**, the symbol from the set  $\{0, 1, ?, C\}$  with which a **minterm** in the **truth table** is associated; there is no analogue in **CNA**

## P

**Parsimonious Solution** a **solution** type in **QCA** that assumes some **remainders** in the **truth table** to be sufficient for the **outcome** (**simplifying assumptions**); see also *Conservative Solution*, *Intermediate Solution*, and *Search Strategy*

**Path** also *causal path*; in **QCA**, a **disjunct** in a **model**; in **CNA**, a sequence of **factor levels**  $\langle A_1, \dots, A_n \rangle$  such that every  $A_i$ , for  $1 \leq i < n$ , appears in the **antecedent** of an **atomic solution formula** and  $A_{i+1}$  in its **consequent**

**PI**  **Prime Implicant**

**PI Chart**  **Prime Implicant Chart**

**Positive Minterm** also *sufficient minterm*; in **QCA**, a **minterm** with an **output value** of “1” that must be covered by a **prime implicant** in the **prime implicant chart**; see also *Negative Minterm* and *Remainder*

**PRI**  **Proportional Reduction in Inconsistency**

**Prime Implicant** abbr. **PI**; in the **Quine-McCluskey algorithm** and **QCA**, a component of the **PI Chart** along the rows; after the decomposition of the **PI Chart**, a potential disjunct of a **model** describing one causally interpretable route to the **outcome**; the equivalent of a **minimally sufficient condition** in **CNA**

**Prime Implicant Chart** abbr. **PI chart**; also *prime implicant table*; a central component of the **Quine-McCluskey algorithm** in the form of a table in which columns correspond to the **positive minterms**, rows correspond to the **PIs**, and crosses signal that a **PI** covers a **positive minterm**; an example of such a chart is given in Table 9:

Table 9: A typical prime implicant chart

	0	1	2	3	5	8	10	11	12	13	14	15
PIs	abcd	abcD	abCd	abCD	aBcD	Abcd	AbCd	AbCD	ABcd	ABcD	ABCd	ABCD
ab	x	x	x	x	-	-	-	-	-	-	-	-
AB	-	-	-	-	-	-	-	-	x	x	x	x
AC	-	-	-	-	-	-	x	x	-	-	x	x
Ad	-	-	-	-	-	x	x	-	x	-	x	-
bC	-	-	x	x	-	-	x	x	-	-	-	-
bd	x	-	x	-	-	x	x	-	-	-	-	-
acD	-	x	-	-	x	-	-	-	-	-	-	-
BcD	-	-	-	-	x	-	-	-	-	x	-	-

**Prime Implicant Table**  [Prime Implicant Chart](#)

**Primitive Expression**  [Minterm](#)

**Principle of Duality**  [Duality](#)


**Procedure of Causal Inference** an algorithm that takes empirical data as input and outputs a set of causal models that fit that data

**Proposition** any declarative statement that is free from ambiguity, context-sensitivity and either **true** or **false**, and not both; e.g.: “The earth is flat.”

**Propositional Logic** a logical system that results from an interpretation of a **Boolean algebra** and that is used to describe and investigate logical relations among **extensional propositions**

**Proportional Reduction in Inconsistency** abbr. PRI; a measure of fit proposed by [Charles C. Ragin](#) to compute the degree to which a **minterm** is as **sufficient** for an **outcome** as it is sufficient for the **negation** of this **outcome**; for more details, see [Schneider and Wagemann \(2012, 242-244\)](#) and [Thiem and Duşa \(2013b, 63-64, 69-70\)](#)

## Q

**QCA**  [Qualitative Comparative Analysis](#); also the name of a **QCA** software package for the R environment by [Adrian Duşa](#) and [Alrik Thiem](#) ([Duşa and Thiem, 2014](#); [Thiem and Duşa, 2013a](#)); up to version 1.1-4, the QCA package was a stand-alone package, starting with version 2.0, it has been demoted to a gateway package to the **QCAGUI** package

**QCA3** a **QCA** software package for the R environment by Ronggui Huang; see [Huang \(2014\)](#)

**QCAGUI** a fork and graphical interface of the **QCA** software package for the R environment by [Adrian Duşa](#); see [Duşa \(2016\)](#)

**QCApro** a successor package to the **QCA** software package for the R environment by [Alrik Thiem](#) that has developed from **QCA** version 1.1-4; see [Thiem \(2016\)](#)

**Qualitative Comparative Analysis** abbr. QCA; a **CCM** introduced by [Charles C. Ragin](#) in the mid-1980s ([Ragin, 1987](#)); nowadays a family of four related variants: **csQCA**, **fsQCA**, **mvQCA** and **gsQCA**

**Quine-McCluskey Algorithm** abbr. *QMC*, *QM* or *Q-M*; a two-stage **minimization** procedure developed by Willard v. O. Quine (philosopher; [Quine, 1959](#)) and Edward McCluskey (electrical engineer; [McCluskey, 1965](#)); the first stage turns the set of all **positive minterms** in a **truth table** into a set of **PIs**; the second stage constructs the **PI chart** from the **PIs** and the **positive minterms**, and decomposes this chart to find a (set of) **minimal sum model(s)**

## R

**Raw Coverage**  [Coverage](#)

**Reduction**  [Minimization](#)

**Redundancy** the fact of a [condition](#) being no [INUS condition](#) or no [PI](#) in a [model](#)

**Regularity Theory** a (philosophical) theory that analyzes causation in terms of invariable patterns of succession and implicational [difference-making](#); for more details, see [Baumgartner \(2008\)](#)

**Relevance of Necessity** abbr. RoN; a measure of fit proposed by [Carsten Schneider](#) and [Claudius Wagemann](#) to describe the trivialness and relevance of a [necessary condition](#); for more details, see [Schneider and Wagemann \(2012, 236\)](#)

**Remainder** also *logical remainder*; in [QCA](#), a [minterm](#) for which no [output value](#) has been determined; in [truth tables](#), usually denoted by “?”; there is no analogue in [CNA](#); see also *Negative Minterm*, *Positive Minterm*, and *Counterfactual*

**RoN**  [Relevance of Necessity](#)

**Row Dominance** a [minimization](#) criterion in the [Quine-McCluskey algorithm](#) that eliminates [PIs](#) which cover [minterms](#) in the [PI chart](#) that another [PI](#) also covers but cover fewer [minterms](#) in total; see also *Minimal Disjunctivity* and *Minimal Sum Model*

## S

**Saturation** the fact of a [truth table](#) showing no [remainders](#); see also *Limited Diversity*

**Search Strategy** when confronted with [limited diversity](#), [QCA](#) provides three search strategies, which produce the [parsimonious](#) (QCA-PS), the [intermediate](#) (QCA-IS), and the [conservative solution type](#) (QCA-CS), respectively

**Sensitivity** the degree of change in the output of a [CCM](#) analysis that results either from perturbations in input variables ([data](#), [factor frame](#)), throughput variables ([membership functions](#), [thresholds](#), [inclusion](#) and [frequency cut-offs](#)) or both; see [Thiem \(2014a, 640\)](#)

**Set** a collection of elements such that it is always possible to determine whether a given element is or is not a member of the set; sometimes specified by enumeration (list method), sometimes by a property (rule method)

**Set Membership Function**  [Membership Function](#)

**Set Membership Score** the degree to which an object belongs to a [set](#); created by means

of **calibration**

**Set-Theoretic Methods**  **Configurational Comparative Methods**

**Set Theory** also *theory of sets of points*; a branch of **Boolean algebra** most prominently axiomatized by Ernst Zermelo and Abraham Fraenkel (**Fraenkel**, **Bar-Hillel** and **Levy**, 1973)

**Simplification**  **Minimization**

**Simplifying Assumption** in **minimization** by means of the **Quine-McCluskey algorithm**, a **remainder** whose **output value** is set to “1” without requiring it to be covered by a **PI** in the **PI chart**; see also *Limited Diversity* and *Positive Minterm*

**Solution** the end product of **QCA** and **CNA** after all **redundancies** have been eliminated by means of **minimization**; consists of one or more **models**; see also *Ambiguity*

**Solution Type** in **QCA**, three solution types exist: the **conservative** one, the **intermediate** one, and the **parsimonious** one

**Standard Analysis** a procedure in the **fs/QCA** software that generates all of **QCA**’s three **solution types**; see also *Enhanced Standard Analysis* and *Theory-Guided/Enhanced Standard Analysis*

**STMs** abbr. **Set-Theoretic Methods**

**Sufficiency** a functional dependency based on Boolean concepts; if  $A$  is sufficient for  $B$ , then the **conjunction** of  $A$  and  $\neg B$  is false; see also *Implication*

**Sufficient Condition** a **condition** that is **sufficient** for the **outcome**; in other words, an expression that appears in the **antecedent** of a true **implication**

**Sufficient Minterm**  **Positive Minterm**

**Subset** a binary relation in **set theory**; a collection of elements that is part of a larger collection of elements; denoted by “ $\subset$ ” for strict subsets and “ $\subseteq$ ” for non-strict subsets

**Superset** a binary relation in **set theory**; a collection of elements that includes a smaller collection of elements; denoted by “ $\supset$ ” and “ $\supseteq$ ” for non-strict supersets

**Switching Circuit Theory** also *algebra of switches*; a branch of **Boolean algebra** for the analysis of switching circuits in electrical engineering

## T

**Table of Combinations**  **Truth Table**

**Tautology** in **propositional logic**, a complex **proposition** that is true under all possible

**truth value** assignments to its component **propositions**; e.g.:  $[(A \Rightarrow B) \wedge A] \Rightarrow B$

**T/ESA**  **Theory-Guided/Enhanced Standard Analysis**

**Theory-Guided/Enhanced Standard Analysis** abbr. T/ESA; a procedure proposed by [Carsten Q. Schneider](#) and [Claudius Wagemann](#) for enhancing **parsimonious** and, ultimately, **intermediate solutions** by, in addition to **ESA**, breaking the link between the set of **simplifying assumptions** and the separation of **easy** and **difficult counterfactuals** in this set as implemented in the derivation of **intermediate solutions** by the **fs/QCA** software; for more details, see [Schneider and Wagemann \(2013\)](#)

**Temporal Qualitative Comparative Analysis** abbr. tQCA; a technique proposed by [Neal Caren](#) and [Aaron Panofsky](#) for incorporating auxiliary factors in **csQCA** that indicate temporal order between the **levels** of the **exogenous factors**; for more details, see [Caren and Panofsky \(2005\)](#) and [Ragin and Strand \(2008\)](#)

**Threshold** also *calibration threshold*; a value from a **base variable** pegged to an **anchor** for the purpose of performing **calibration** by means of **assignment by transformation**

**Throughput Parameter** in sensitivity diagnostics, any parameter over which the researcher has discretionary control in the application of **CCMs**; see also *Input Parameter*

**Tosmana** Tool for Small-n Analysis; a computer program for **QCA** developed by Lasse Cronqvist; see [Cronqvist \(2016\)](#)

**tQCA**  **Temporal Qualitative Comparative Analysis**


**TRUE** a **truth value** in **propositional logic**; denoted by “T” and commonly also by “1”

**Truth Table** also *function table* or *table of combinations*; in **QCA**, a matrix of all **minterms** derivable from a given set of **exogenous factors** to which a column of **output values** is appended; in **CNA**, a table of observed **minterms** across all **factors** in the **factor frame**

**Truth Value** the value **FALSE** and the value **TRUE**

**Two-Step Approach** a technique proposed by [Carsten Q. Schneider](#) and [Claudius Wagemann](#) for reducing **limited empirical diversity** by sequencing **QCA** runs with split **factor frames**; for more details, see [Schneider and Wagemann \(2006\)](#)

## U

**Union** a **set-theoretic** operation; denoted by “ $\cup$ ”;  **Disjunction**; the union  $A \cup B$  of two sets  $A$  and  $B$  is shown in [Figure 3](#):

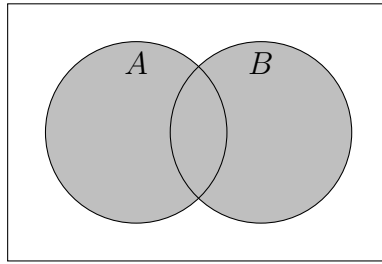


Figure 3: A Venn diagram of the union  $A \cup B$  of sets  $A$  and  $B$

**Unique Coverage** that part of a **prime implicant's** raw **coverage** which is not shared by any other **prime implicant** within the same **model**

**Universal Set** a **set-theoretic** term; a **set** containing all elements; denoted by "U"; U for two sets  $A$  and  $B$  is shown in Figure 4:

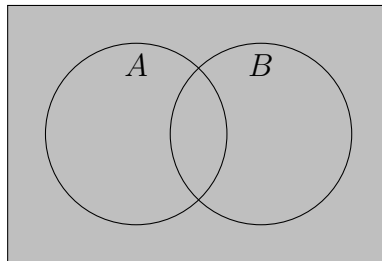


Figure 4: A Venn diagram of U for sets  $A$  and  $B$

## V

**Value Score Notation** abbr. VSN; a system of notation proposed by [Alrik Thiem](#) that allows the integration of **fsQCA** and **mvQCA** and is the basis for **gsQCA**; under VSN, an observation is recorded as  $X\{v\}s$ , where  $X$  is the factor,  $\{v\}$  the value (**level**) and  $s$  the **membership score** in the set of objects where  $X$  takes on  $v$ ; see also *Curly-Bracket Notation*

**Venn Diagram** a type of diagram introduced by John Venn capable of representing all possible set-theoretic relations between a finite collection of different **sets**; see also *Empty Set*, *Set Theory*, *Subset*, *Superset* and *Universal Set*; a Venn diagram showing the set difference of  $A$  in  $B$  is presented in Figure 5:



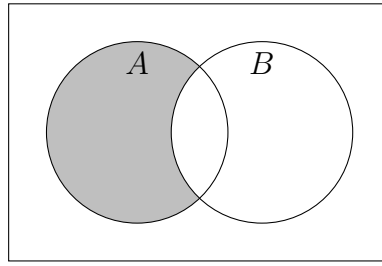


Figure 5: A Venn diagram of  $A \setminus B$

**Veitch-Karnaugh Map** a graphical device for the purpose of Boolean **minimization**; a Veitch-Karnaugh map for the Boolean function  $ABC \vee AB\bar{C} \vee A\bar{B}C \vee \bar{A}\bar{B}C$  is presented in Figure 6:

	$\overbrace{\hspace{1.5cm}}^A$			
	$\overbrace{\hspace{1.5cm}}^C$			
	0	1	5	4
B	2	3	7	6
	0	0	1	1

Figure 6: Karnaugh map for the Boolean function  $ABC \vee AB\bar{C} \vee A\bar{B}C \vee \bar{A}\bar{B}C$

**VSN** Value Score Notation

**W**

**X**

**Y**

**Z**

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