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SET-THEORETIC APPROACH TO MATURITY MODELS

Lester Allan Lasrado

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English Abstract

Despite being widely accepted and applied, maturity models in Information Systems (IS) have been criticized for the lack of theoretical grounding, methodological rigor, empirical validations, and ignorance of multiple and non-linear paths to maturity. This PhD thesis focuses on addressing these criticisms by incorporating recent developments in configuration theory, in particular application of set-theoretic approaches. The aim is to show the potential of employing a set-theoretic approach for maturity model research and empirically demonstrating equifinal paths to maturity. Specifically, this thesis employs Necessary Condition Analysis (NCA) to identify maturity stage boundaries as necessary conditions and Qualitative Comparative Analysis (QCA) to arrive at multiple configurations that can be equally effective in progressing to higher maturity. Furthermore, this thesis prescribes methodological guidelines consisting of detailed procedures to systematically apply set theoretic approaches for maturity model research and provides demonstrations of its application on three datasets.

The thesis is a collection of six research papers that are written in a sequential manner. The first paper reviews literature on maturity models in IS, identifies research gaps and proposes use of configurational theory to address these challenges. The second paper conceptualizes stage boundaries as necessary conditions and demonstrates the application of Necessary Condition Analysis (NCA) on a social media maturity dataset. Building on the second paper, the third paper conceptualises maturity stage characteristics in terms of configurations using Qualitative Comparative Analysis (QCA). Overall, the third demonstrates empirically the existence of multiple paths to maturity and provides IS researchers with a six-step procedure and detailed guidelines to systematically apply set theoretic approaches to maturity models (STAMM). The fourth paper then uses the social media maturity dataset, computes maturity scores using different quantitative methods prescribed in maturity models literature and proposes recommendations for maturity model designers. The fifth and sixth papers are demonstrations of applicability of STAMM on different datasets. The fifth replicates and extends a prior research study on ITIL maturity and compares the findings with the results using STAMM. Finally, the sixth paper argues for a multi-method approach by combining STAMM and PLS-SEM in understanding the conditions associated with IT service management (ITSM) maturity.

This PhD thesis contributes to the academic discussion on how maturity occurs through configurations. The key contribution is STAMM, a set-theoretic procedure

model and method, which employs FsQCA and NCA to empirically demonstrate multiple paths to maturity (or equifinality). It also contributes to set-theoretic approaches, in particular QCA and NCA. Finally, this thesis contributes to multi-method approach by harmoniously integrating PLS-SEM, QCA and NCA, thus adding to the limited body of multi-method literature.

Dansk Abstrakt

Til trods for at være bredt accepteret og anvendt, er maturity modeller i Information Systems (IS) blevet kritiseret for mangel på teoretisk fundament, metodisk substans, empiriske valideringer samt ignorering af multiple og non-lineære veje til maturity. Især kritikken om at modenhed ikke nødvendigvis følger en lineær sekvens, men snarere konfigurationer af multiple komplekse organisatoriske og miljømæssige forhold, er fortsat ikke blevet adresseret. Denne PhD afhandling fokuserer på at imødegå denne langvarige kritik, ved at inkorporere nylige resultater inden for konfigurationsteori, hovedsagelig anvendelse af set-teoretiske tilgange. Målet er at demonstrere potentialet af at anvende en set-teoretisk tilgang til maturity models forskning samt empirisk at vise ligeværdige veje til maturity. Mere specifikt benytter denne afhandling Necessary Condition Analysis (NCA) til at identificere maturity stage boundaries, som nødvendige betingelser og Qualitative Comparative Analysis (QCA) til at nå frem til multiple konfigurationer, som alle kan være lige effektive i at transformere objekter til højere maturity. Denne afhandling beskriver dertil de metodologiske retningslinjer, som består af detaljerede procedurer til systematisk at anvende set-teoretiske tilgange til modenhedsmodelforskning og illustrerer dets anvendelse på tre konkrete datasæt.

Afhandlingen består af en samling af seks forskningsartikler, som er skrevet ud fra en sekventiel logik. Artikel I afdækker litteraturen omkring maturity modeller i IS, identificerer mangler og anbefaler anvendelse af konfigurationsteorien til at adressere disse udfordringer. Artikel II konceptualiserer trin barrierer som nødvendige betingelser, og demonstrerer anvendelsen af Necessary Condition Analysis (NCA) på et digitalt modenhedsdatasæt fra sociale medier. Samlet set demonstrerer artikel III empirisk eksistensen af multiple veje til modenhed og giver IS forskere en seks-trins procedure samt detaljerede retningslinjer til systematisk at anvende teoretiske tilgange til maturity models (STAMM). Artikel IV benytter datasættet om social media modenhed og beregner modenhed scoren ved at anvende forskellige kvantitative metoder beskrevet i maturity models litteraturen samt foreslår anbefalinger til maturity model forskere. Artikel V og VI demonstrerer anvendelsen af STAMM på forskellige datasæt. Paper V replicerer og udvider et tidligere forskningsstudie om ITIL modenhed, og sammenligner resultaterne med resultaterne ved at bruge STAMM. Endelig argumenterer paper VI for en multi-metode tilgang ved at kombinere STAMM

og PLS-SEM for at forstå betingelserne associeret med IT service management (ITSM) modenhed.

Denne PhD afhandling bidrager til den faglige diskussion om, hvordan maturity opstår gennem konfigurationer. Det centrale bidrag er STAMM, en set-teoretisk procedure model og metode, som anvender FsQCA og NCA til empirisk at demonstrere multiple veje til modenhed (eller ækvivalens). Det bistår også til set-teoretiske tilgange, specielt QCA og NCA. Endelig bidrager denne afhandling til multi-metode tilgange ved harmonisk at integrere PLS-SEM, QCA og NCA, og dermed til den begrænsede mængde af multi-metode litteratur.

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List of Abbreviations

QCA	Qualitative Comparative Analysis
FsQCA	Fuzzy set Qualitative Comparative Analysis
NCA	Necessary Condition Analysis
STA	Set Theoretic Approach
IS	Information Systems
STAMM	Set Theoretic Approach to Maturity Models
ITSM	IT service management
ITIL	Information Technology Infrastructure Library
PLS	Partial Least Squares
PLS-SEM	Partial Least Squares- Structural Equation Modeling
NBI	Networked Business Initiative

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1. Introduction

When most people in Information Systems research think about maturity models, they either refer to Capability Maturity Model (Paulk et al. 1993), Crosby's Maturity Grid (Crosby 1980) or Nolan and Gibson (1974)'s stage of growth model. Today, maturity models in information systems (IS) academic research are understood as tools that can (a) aid the facilitation of internal and/or external benchmarking, (b) showcase possible process and outcome improvements, and (c) provide guidelines for the evolutionary process of organizational development and growth (Mettler et al. 2010; Wendler 2012). Maturity models in IS industry practice are normative and prescriptive by nature (Davenport and Harris 2007; Lahrman et al. 2011; Nolan and Gibson 1974). However, developing a theoretically informed, methodologically rigorous, and empirical validated maturity model is subject to intense debate and fierce critique in IS research (Becker et al. 2010; King and Kraemer 1984) and related disciplines (Andersen and Henriksen 2006; Kazanjian and Drazin 1989; Wendler 2012). Scholars have been debating back and forth on maturity models' design without really maturing on argumentation types, methodological techniques, or evidential grounds. In particular, the criticism that maturity does not necessarily occur through a linear sequence (King and Kraemer 1984; Solli-Sæther and Gottschalk 2010), but instead through configurations of multiple complex organizational and environmental conditions, also known as "equifinality" has been left unaddressed.

My PhD project addresses this long standing criticism by incorporating recent developments in configuration theory, in particular application of set-theoretic approaches (STA) (Bedford et al. 2014; Fiss 2011). After reviewing the relevant literature on configuration theory from the discipline of strategic management (Bedford and Sandelin 2015; Doty et al. 1993; Fiss 2011; Miller 1996), I found similarities between maturity models and configurations in terms of (1) *underlying principles*: both maturity models and configurations allow users to cognitively simplify a complex environment by highlighting commonalities, allowing comparisons and providing holistic understanding, and (2) *problems encountered*: like maturity models, configurations also have to move beyond traditional linear thinking as existing statistical techniques fail to account for this complexity. While the lack of empirical research for conceptualizing and testing configurations has been traditionally attributed to *lack of appropriate methods*, the set-theoretic approach has addressed these methodological concerns in the discipline of strategic management (Bedford and

Sandelin 2015; Fiss 2007; Fiss 2011). Given that maturity model research in IS faces isomorphic problems and challenges similar to that of configurations, I set out on my PhD journey to investigate if configuration theory in general and set-theoretic approaches (STA) in particular can address this long standing challenge in maturity model research. In particular, I employ two methods (a) *Qualitative Comparative Analysis (QCA)* (Ragin 1987; Ragin 2008; Thiem and Dusa 2012; Wagemann and Schneider 2010), and (b) a novel method called *Necessary Condition Analysis (NCA)* (Dul 2016c; Vis and Dul 2016)¹ for designing maturity models.

The outcome of the PhD project is the knowledge contribution of an alternative approach to designing empirically founded and methodologically rigorous maturity models. I call this “A Set Theoretic Approach for Maturity Models (‘STAMM’), basically comprising of a detailed step by step procedure for applying this approach. Furthermore, I test the application of STAMM on three different datasets (also referred to as demonstrative cases)². In the process of doing so, I continuously improve and extend the procedure, while documenting the challenges and limitations. In particular, I extend the procedure to meet the needs of quantitative researchers in the domain of maturity models interested in hypothesis testing using standard correlational techniques (regression, PLS-SEM)³. One such improvement is showcased in demonstrative case 3, wherein STAMM is integrated with a well-established regression technique (PLS-SEM) to produce valuable insights in the context of ITSM maturity.

1.1 Scope of the PhD Project

Based on the detailed review of maturity models research in IS (paper I, IV) and supported by other literature reviews on maturity models (Becker et al. 2010; Mettler et al. 2010; Plattfaut 2011; Pöppelbuß et al. 2011; Wendler 2012), I classify the domain of maturity model research into four broad categories:

¹ In this thesis, I group QCA and NCA under the umbrella of Set Theoretic Approaches (STA). Some scholars might debate this grouping as NCA does not satisfy all three features shared by STA’s (see (Wagemann and Schneider 2010), page 10). I have done so for three main reasons: (1) From the three empirical studies in this thesis, I argue and prove that NCA complements QCA, (2) the makers of NCA (Dul 2016c) also argue that NCA should be used as a precursor to identify necessary conditions before using QCA, and (3) finally for ease of presentation.

² In all my empirical studies, I have used Fuzzy-set Qualitative Comparative Analysis (FsQCA) due its advantages over Crisp set QCA. I have discussed the advantages in Chapter 4.

³ Mostly interested to understand associations between maturity and its contextual factors (conditions) and performance.

1. *Maturity model design*⁴: the main objective of these researchers is constructing a new maturity model. Some of largely cited models are: EDP stage of growth model (Nolan and Gibson 1974), Intranet maturity model (Damsgaard and Scheepers 1999), and e-government maturity model (Andersen and Henriksen 2006).
2. *Maturity model application (assessment)*: the main objective here is application of maturity models in specific domains and maturity assessments/benchmarking of organisations in general. The researchers in this category need to have developed a measurement instrument (usually surveys) based on their own existing maturity models (Raber et al. 2012; Raber et al. 2013) or based on well-established models from the industry (e.g. ITSM process maturity Wulf et al. (2015), Marrone and Kolbe (2011a)).
3. *Maturity model validation*: the main objective here is to validate existing maturity models. However, validation studies are very rare, especially on models developed by researchers themselves (Wendler 2012). While Nolan and Gibson (1974)'s model was extensively debated (Drury 1983; King and Kraemer 1984), validation studies of other models produced by researchers have been rare. While there are some quantitative studies looking at validation of popular industry models like CMM (Dekleva and Drehmer 1997)⁵, ITSM (Marrone and Kolbe 2011a; Wulf et al. 2015), and a few others, the dominant method for validation is mostly qualitative case studies.
4. *Meta- Research ("research about research")*: the main objective here is to reflect on overall research "about" maturity models, improve research practices and methods, and set the next research agenda for the field in general. For example, procedure models by Becker (2011), Solli-Sæther and Gottschalk (2010), and De Bruin et al. (2005), articles by Mettler (2009) and Plattfaut (2011) calling for a design science approach and use of process theories respectively, and introduction of methods like Rasch analysis (Dekleva and Drehmer 1997; Lahrman et al. 2011) for inductive maturity design are classified into this category.

A knowledge contribution to maturity model research could be made in any or all of these categories. It is understood that a significant contribution to "meta- research", automatically contributes to the other three categories. Moreover, the maturity model

⁴ This category only includes models that are developed by researchers and not by consultancies (e.g. DELTA-Model-Accenture (2013), digital maturity (Kane et al. 2015)) and the industry (e.g. BPM maturity, CMM, ITSM/ITIL, etc).

⁵ The cited studies are quantitative validation of maturity. As you can see, articles by Marrone and Kolbe 2011 and Wulf et al. 2015 are shown in both assessment and validation. This is done on purpose, because most studies that conduct assessment of maturity using surveys, also validate maturity using the same instrument. Validation is usually done testing for associations between maturity and expected outcomes like performance or business benefits.

research categories can be also understood as steps to conducting rigorous maturity model research. These steps are not isolated silos, but should be seen as an iterative cycle of taking maturity model research forward as illustrated in figure 1.

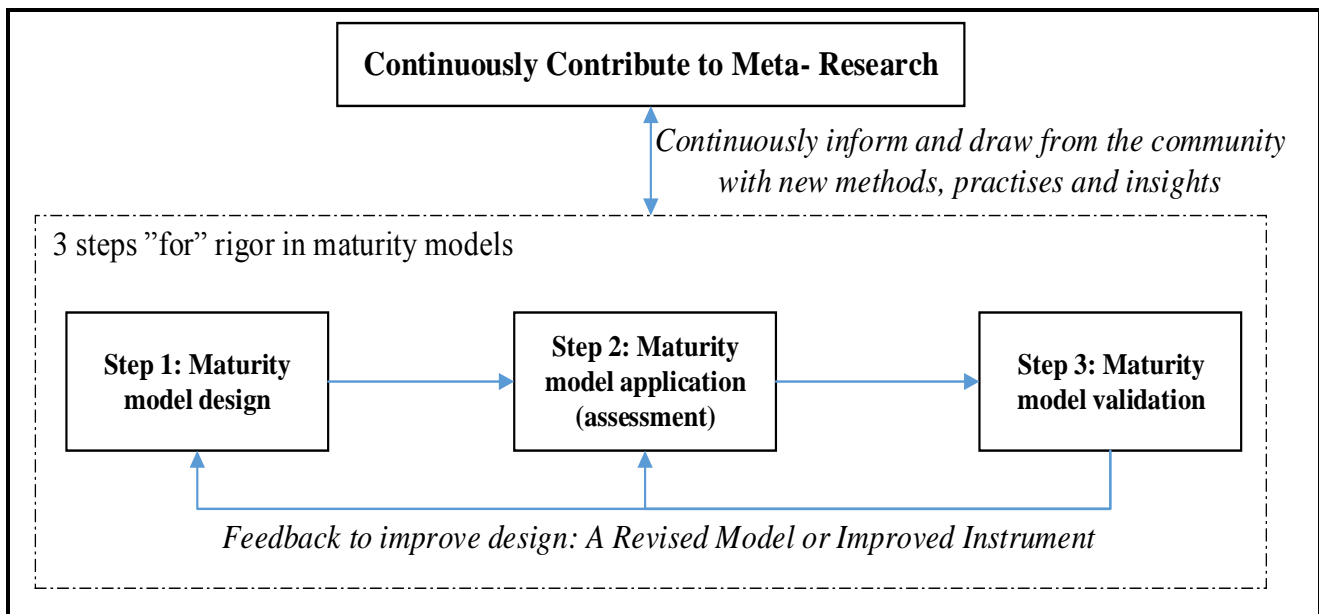


Figure 1: Research in maturity model research. Adapted from Wendler (2012).

For this PhD dissertation, I have positioned myself as a “meta-researcher in maturity model research” by contributing with a new approach to maturity model research. Next, I identify the audience that will benefit from reading this thesis. I emphasize that maturity comparison is meaningful only when the number of cases are large enough to cover the diversity of organisations. Moreover, I subscribe to a quantitative tradition of comparative research (methodological level) and understand rigor as use of mathematical and statistical techniques to indentify empirical facts. Therefore, the intended audience of this thesis are maturity model researchers mostly interested in moderate or large N studies⁶.

Furthermore, the key focus of this PhD project is methodological development. Therefore, the papers included and the demonstrative datasets presented in this PhD dissertation focus more on the methods for designing and developing maturity models rather than the phenomena of specific maturity models themselves (e.g., Social Media or ITSM maturity). Their purpose is just to serve as demonstrations of the set-theoretical approach to maturity models (STAMM). Therefore, I neither make nor pretend to make causal claims for the resulting maturity models and their relationships

⁶ I use the term moderate or large N to stay in sync with the QCA community (as this is my primary method). Moderate N (>50 samples) or large N(>300 samples) should be understood as survey sample size of greater than 50 and greater than 300 respectively. It could be survey samples or case studies.

to organizational capabilities and business outcomes. For example, in empirical study 3 (ITSM maturity), although I state that the findings contribute to the ITSM community, I formulate the relationships as “associations” and not “causal mechanisms”.

1.2. Research Questions

Given the widespread adoption of maturity models in Information systems (IS) research, it is quite surprising to find the lack of rigor⁷ in terms of use of theory and empirical methods for the design of maturity models. Moreover, it is alarming to notice the number of conceptual maturity models (see paper I, IV) without any assessment and validation. For example, through a review of 61 maturity models on business process management (BPM), Tarhan et al. (2016) concluded that the BPM academic community has emphasized mostly on developing maturity models and not empirically evaluating them.

While recent publications by meta-researchers (Becker et al. 2011; Mettler 2009; Pöppelbuß and Röglinger 2011) proposing a design science paradigm has had some influence on improving the rigor of maturity model development process, the number of conceptual models⁸ simply outweigh design-oriented ones (Wendler 2012). Moreover, there have been continuous calls to the research community by meta-researchers for new and better theoretical perspectives, applicable methods, improved practices and systematic procedures for developing rigorous maturity models. The two important calls were by Becker et al. (2010) and Solli-Sæther and Gottschalk (2010):

“IS literature has mostly ignored theoretical approaches to maturation; the process of becoming more mature has been understood rather vaguely..Maturity models in IS requires conceptualizations and analytical perspectives better grounded in theory” (Becker et al. 2010)

⁷ Wendler (2012) also questioned the “rigor” of the maturity models stating that only 7 out of 105 maturity models reviewed by him have used empirical i.e. qualitative or quantitative methods for development or validation (paper I).

⁸ While some of these conceptual models use theories (Resource based view, Contingency theory etc.) to construct their models, others (>70%) simply use the structure of popular maturity models like CMM, BPM, and Nolan to populate the stage characteristics. The design science paradigm (Hevner et al. 2004) states that “rigor is achieved by appropriately applying existing foundations and methodologies through application of computational and mathematical methods to evaluate the quality and effectiveness of artifacts”. Using this criteria by Hevner et al. (2004), one can classify most of the maturity models as non-rigorous (as validation studies are so rare). Even when validation is done it is mostly using a single case study and not quantitative research (refer paper I and these articles (Becker et al. 2010; Mettler et al. 2010; Plattfaut 2011; Pöppelbuß et al. 2011; Wendler 2012)).

Whereas most existing research and initiatives focus on development of growth models by suggesting a number of stages, benchmark variables, and the path of evolution between stages, a systematic analysis of the modeling process is currently lacking. (Solli-Sæther and Gottschalk 2010)

In an attempt to answer these calls to research and address the long standing criticism of “equifinality”, I first formulate the three main objectives of this thesis: (a) understand the *as-is* situation of maturity model research in IS, (b) address the challenge of conceptualizing multiple paths to maturity and (c) provide the maturity model research community with a systematic approach for developing methodologically rigorous maturity models. With these objectives in mind, I formulate the following research questions in table 1.

Table 1: Research Questions.

Objective 1	RQ1: What is the current state-of-the-art of maturity models research in Information Systems (IS) ?	
	a) What are the different components constituting a maturity model?	First, I deconstruct the maturity model and describe its general structure. I do so by reviewing maturity models in IS research till date (Paper I)
	b) What are the different quantitative methods and techniques employed for maturity model research?	I review the existing quantitative methods and techniques both in maturity model research and beyond (Paper I and IV). After this search process, I found that none of the methods could model multiple paths to maturity.
Objective 2	RQ2: How can multiple paths to maturity be conceptualized and empirically demonstrated?	
	a) How can configuration theory be used to conceptualise multiple paths to maturity?	Here I conceptualise maturity models through a configurational perspective. I then use set-theoretic approaches ⁹ to empirically demonstrate existence of “equifinality” using my first dataset (paper III).
	b) How can set-theoretic approaches empirically demonstrate multiple paths to maturity?	Now that I had developed an approach (STAMM) that could applied on one dataset, I

⁹ The process of conceptualization and application of the methods (QCA and NCA) was not sequential but parallel. After preliminary conceptualization, I realised QCA alone would not work. I then discovered NCA, while reviewing different quantitative methods which resulted in paper II and III.

	proceed to test it out on other datasets.
Objective 3	RQ3: How can the set-theoretic approach to maturity models (STAMM) be combined with statistical methods?
	I acquired two more datasets from fellow IS maturity model researchers ¹⁰ wherein the data collection was more suited for employing correlational techniques. This motivated me to test if the approach developed (STAMM) could be employed in different datasets and thus test its limitations. I acknowledge that there might be many more different datasets, but in this thesis, I attempt to cover two different datasets.

1.3 Research Process

This PhD study follows a paper-based format. The research progressed in a systematic and iterative way (figure 4), following the design science approach for developing artifacts (Becker et al. 2011; Hevner et al. 2004; Peffers et al. 2007). I selected a design-science research approach as I was trying to answer "how to" type of a question¹¹. According to Hevner et al. (2004), design-science research “must produce a viable artifact in the form of a construct, a model, a method, or an instantiation”. I argue that the final product of this PhD “A Set Theoretic Approach for Maturity Models or STAMM”, is an artifact which is both a procedure model and a method for conducting data-driven rigorous maturity model research. While there are many frameworks and guidelines proposed on how to conduct design science research, I followed the design science research (DSR) approach proposed by Peffers et al. (2007) as illustrated in figure 2.

However, in this PhD thesis I just used DSR as a template to guide the research process in a systematic manner. The proponents for DSR advocate that a strong DSR contribution should involve contribution to design theory and design principles. I make no such claims in this thesis and hence make no contribution to the design theory or the design principles.

¹⁰ I tried to contact many researchers and acquire more datasets, however I was successful in acquiring just these two (more reflections in data collection).

¹¹ Moreover, the research questions under consideration, as well as the intended final results (end goals) envisioned, determined the suitability of methods (Mårtensson et al. 2016).

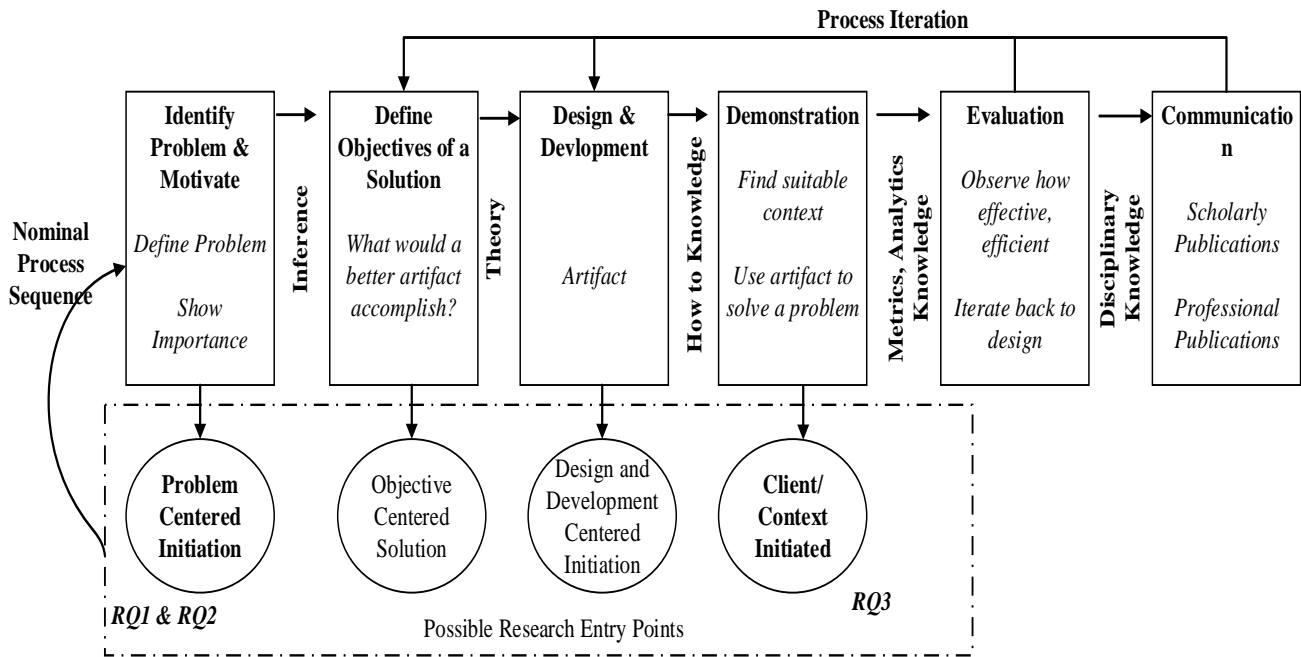


Figure 2: Design Science Research approach for STAMM (Peffers et al. 2007).

Following Peffers et al. (2007)'s model and recommendations by Gregor and Hevner (2013), my research process (figure 3) included identifying problem situation (lead to my research questions) by reviewing literature on maturity models in IS. The next step was designing an artifact (STAMM) to address those problems, demonstrating and testing the artifact in practice (using three datasets), and in the process evaluating its applicability and generalizability in practice¹². However, design is considered a search process to discover an effective solution to a problem and design science research requires the application of rigorous methods in both the construction and evaluation of the designed artifact (Gregor and Hevner 2013; Hevner et al. 2004). I conducted my initial search process looking for suitable theories and methods that could account for "equifinality". In design science research, these theories and methods are referred to as kernel theories as they advise design solutions and provide theoretical grounding for the artifact (Walls et al. 2004). This search process was influenced by my objectives and philosophical assumptions¹³, which directed me towards methods that were mostly

¹² By practice, I mean both IS researchers and practitioners wanting to design maturity models. It is important that researchers and practitioners are interested in using quantitative approaches (sample size of the data they plan to collect should be greater than 50).

¹³ I argue that the complexity of the concept (measured using a maturity model) can be tackled by systematic comparative procedures, provided there is enough diversity among cases (i.e. data collected). Therefore, the probability of ensuring diversity increases either by purposeful sampling (i.e. carefully select cases representing all maturity stages) or by increasing the sample size of cases, so as to ensure most of the diversity is captured. I subscribed to the second approach; reason being, to use the first approach successfully one should know the cases in advance and be confident

quantitative. After this search process (mostly literature reviews), I concluded that variance theory and its associated methods (e.g. clustering, regression analysis) could not model multiple paths to maturity. Furthermore, while process theories (e.g. lifecycle, evolutionary approaches) can account for equifinality, the methods associated with them fall short when the data collected exceeds few cases ($N > 15$). The final conclusion from this search process was that configurational thinking and set theoretic approaches (STA) was the answer to modelling “equifinality”. Next I developed the first version of the artifact and provided a proof-of-concept demonstration of its applicability on dataset 1 (paper III & II). The artifact, along with its output (social media maturity model & measurement instrument: paper III) were evaluated¹⁴ for proof-of-value. This evaluation occurred through a workshop, with representatives from the case company (dataset 1: NBI).

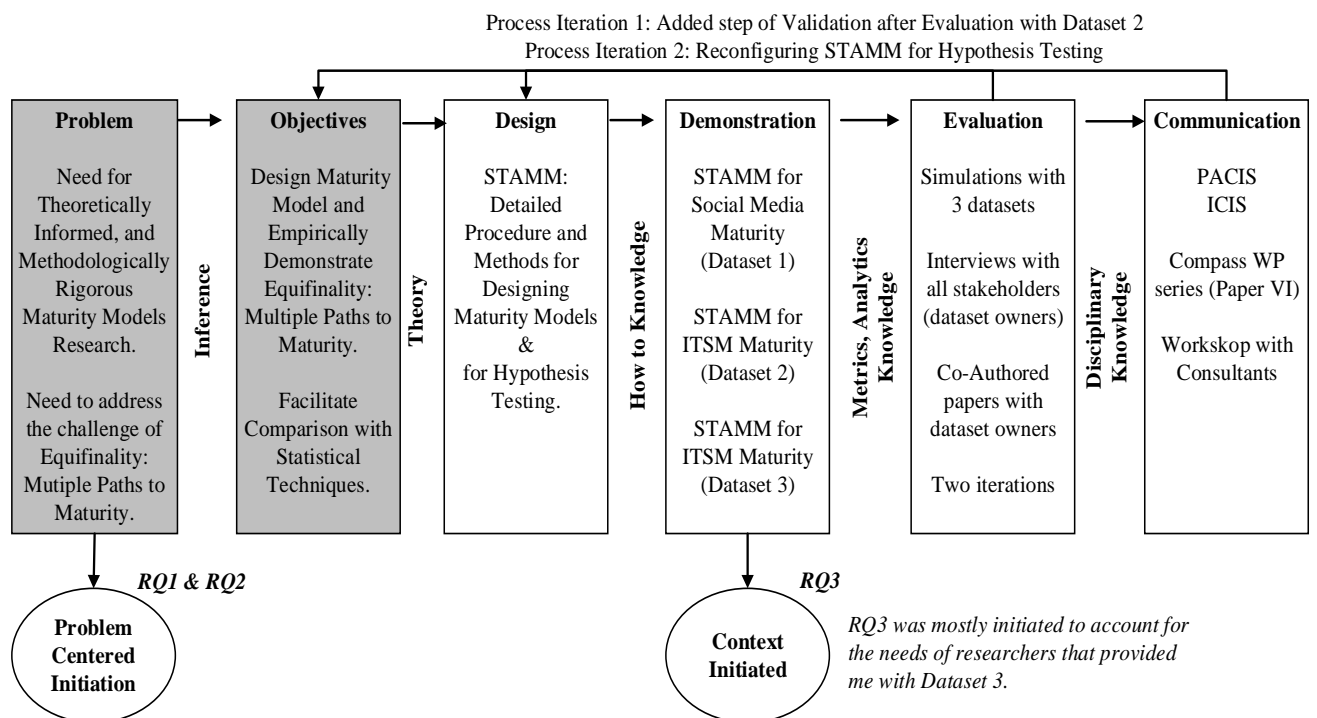


Figure 3: Design Science Research (Problem & Objectives, see section 1.1 & 1.2).

In order to conduct further evaluations of the artifact, I contacted IS researchers conducting maturity model research to share their datasets. The researchers were

that these cases represent the entire reality. Hence I argue the data collection must be large enough ($N > 50$), so that the probability of capturing diversity among cases increases.

¹⁴ Hevner et al. (2004) proposes 5 design evaluation methods. Evaluation in this PhD project was through (i) simulations i.e. execute artifact with (artificial) data; in this thesis data was from real sources, and (ii) scenarios i.e. to demonstrate its utility; in this PhD thesis two scenarios were tested (inductive design of maturity model & hypothesis testing).

contacted via email and a call for datasets was made at the International Conference on Information Systems (ICIS 2016) in Dublin, after the presentation of paper III. While emails did not produce any positive results, after the call at ICIS 2016, two researchers (Marrone and Kolbe 2011a; Wulf et al. 2015) shared their datasets (dataset 2 and 3) with me. However, the purpose of data collection¹⁵ for Wulf et al. (2015) was not for designing maturity models, but rather hypothesis testing (i.e. look for relationship between conditions, maturity and performance). Since design thinking is experimental, “problems and solutions co-evolve as the designer acts not only to resolve known issues, but also to explore the nature of the problem” (Dalsgaard 2014), I went back to my design & development phase and iterated the design of STAMM. I reviewed literature wherein set-theoretic approaches were combined with regression analysis and developed an extended version of STAMM that could be used for hypothesis testing. During this process I maintained reciprocal interaction with my current stakeholders (Marrone and Kolbe 2011b; Wulf et al. 2015), finally evaluating this extended version of STAMM, resulting in paper V and paper VI.

About the Datasets:

Three datasets have been used in this PhD thesis. All three datasets are cross-sectional surveys, but designed differently and for different purposes.

Dataset 1: Social Media Maturity Dataset of Organisations in Denmark (2015-2016)

The first dataset was on social media maturity developed by Networked Business Initiative (NBI). NBI measured digital maturity of organizations in Denmark in terms of five digital technologies and measured 231 organizations¹⁶. The targeted audiences were managers (top and middle management) in Danish organizations looking towards comparing their digital performance (maturity) against their peers. The data was collected through a cross-sectional survey linked to a live dashboard whose primary purpose was comparative benchmarking (details in paper III). The purpose of the makers (NBI consultants) is only benchmarking. I employ STAMM to uncover patterns (configurations) from the dataset and design a maturity model and measurement instrument (paper III).

¹⁵ See individual papers for description of datasets and stakeholders.

¹⁶ Only social media maturity for customer facing activities (PR, Sales) was used in the demonstration of STAMM (check paper III). The main reason being; there are not enough data (low sample size and no diversity) to carry out analysis for the rest of the digital technologies.

Dataset 2: IT Service Management Maturity of Organisations from UK and USA (2009)

For the second demonstration of STAMM, I use the data used in a previous research study (Marrone and Kolbe 2011b; Marrone and Kolbe 2011c) investigating ITIL maturity in the months of April and May 2009 . The survey instrument measures the perception of maturity of ITIL implementation (using a 5 point likert scale similar to CobiT and CMMI maturity). The survey collected data from 491 respondents, of which a subset (N=229) has been used this thesis¹⁷. The survey collects information about all the ITIL process implemented (ITILV2 and ITILV3), perception of challenges of implementing ITIL, realized benefits and other factors like alignment, time since adoption and maturity of the processes implemented. Two papers were published using this dataset (Marrone and Kolbe 2011b; Marrone and Kolbe 2011c) and both of them use univariate statistical techniques to explore associations between ITIL maturity and the different factors. I use STAMM to re-analyse the same dataset, design a maturity model and also compare my findings with that of Marrone and Kolbe (2011b).

Dataset 3: ITSM Maturity of Organisations from Germany, Denmark, and Switzerland (2014)

For the demonstration of STAMM for hypothesis testing, I use a subset of the data¹⁸ (N=127 organizations) used in a recent research study (Winkler et al. 2015; Wulf et al. 2015) investigating ITSM maturity. The survey instrument used was developed and validated as part of that study (Wulf et al. 2015). It measured the levels of the 26 common ITSM processes based on the nomenclature and process descriptions of the widely used ITIL reference model (Wulf et al. 2015). In addition, the survey collected data of contextual factors (referred to as conditions in this PhD thesis) that are considered adequate for ITSM process maturity. The purpose of the makers is both benchmarking tool for practitioners (Winkler et al. 2015) and academic research by studying the associations between ITSM maturity and its contextual factors. For the second purpose, the researchers employ hypothesis testing using PLS-SEM and using STAMM, I aim to contribute to this purpose.

¹⁷ Based on dicussions with Marrone and Kolbe (2011b), it was decided to restrict the data to UK and USA. Moreover, in the data cleaning process, some reponses were booted out due to missing values and random answers. Please refer paper V and article by Marrone and Kolbe (2011b) for the sample characteristics.

¹⁸ I had enough data for PLS-SEM for Internal service providers (N=127). Data for External service providers was very small (N=29), hence using PLS-SEM was not possible (check paper VI).

1.4 Thesis Structure

This PhD thesis consists of seven chapters and a collection of six research papers that are written in a sequential manner (Figure 1). While each paper is written to be self-contained and can be read separately, the individual contributions together provide a coherent answer to the overarching research questions. This first chapter is meant to summarize the research. The rest of the chapters are organized as shown in table 2:

Table 2: An outline and summary of the of the papers.

Chapter (CH)	Paper	Outlet	What does this chapter address?	RQ
CH 2: Research Philosophy	NA	NA	[1] Discussion on research philosophy, which informed my choice of theory and methods.	
CH 3: Maturity Model Research in IS	I IV	IRIS ECIS	[1] Overview of Maturity Model research in IS. [2] Definition of maturity model for this thesis. [3] Components of a maturity model. [4] Quantitative Methods applied to Maturity models research. [5] Why these existing methods are inappropriate for demonstrating multiple paths to maturity.	1a 1b
CH 4: Configurational Approach to maturity model Design: Addressing Equifinality	II III	PACIS ICIS	[1] Conceptualising maturity model as a configuration of conditions. [2] Applying set-theoretic approach as a method to uncover equifinality: (a) Qualitative comparative analysis (QCA) as a primary method, and (b) Necessary Condition Analysis (NCA) to compliment QCA. [3] Presenting the Preliminary version of STAMM i.e. a extended 7-step procedure & for designing a maturity model. [4] Re-configuring STAMM to accomodate traditional statistical methods for maturity model research.	2a 3
CH 5: Demonstration:	V VI	NA	[1] Demonstrating applicability of STAMM: Empirical demonstration and evaluation	2b 3

			<p>results while linking the chapter to the research papers.</p> <p>[2] Critical Reflections on STAMM: Methodological and practical challenges encountered during demonstrations are discussed.</p>	
CH 6: Conclusion	NA	NA	<p>[1] Contributions.</p> <p>[2] Implications.</p> <p>[3] Future work and research agenda.</p>	
Appendix	NA	NA	<p>[1] Set-theoretic approaches in IS research.</p> <p>[2] R codes and Calibration.</p>	

I have made a conscious attempt to avoid repetition of content and to guide the reader through the papers smoothly. I provide an overall summary and synthesis of the papers in the beginning of each chapter. The third chapter is the core of this PhD thesis. It discusses the foundations of configurational approach to maturity model design and deploys the methodological apparatus of set-theoretic approaches (FsQCA in particular) to visualise multiple paths to maturity. It presents the extended version of STAMM (7 step procedure) and the version for hypothesis testing. Chapter 5 are the three empirical demonstrations as discussed in table 2. The final chapter presents the conclusions, limitations and future research agenda.

1.5 Summary of the papers

Paper I: Maturity Models Development in IS Research: A Literature Review (Lasrado et al. 2015)

In Proceedings of the 38th IRIS Selected Papers of the Information Systems Research Seminar in Scandinavia, Volume 6, Oulu, Finland. 2015. (Co-Authors: Ravi Vatrapu & Kim Normann Andersen)

Maturity models are widespread in IS research and in particular, IT practitioner communities. However, theoretically sound, methodologically rigorous and empirically validated maturity models are quite rare. This literature review paper focuses on the challenges faced during the development of maturity models. Specifically, it explores maturity models literature in IS and standard guidelines, if any to develop maturity models, challenges identified and solutions proposed. Our systematic literature review of IS publications revealed over hundred and fifty articles

on maturity models. Extant literature reveals that researchers have primarily focused on developing new maturity models pertaining to domain-specific problems and/or new enterprise technologies. We find rampant re-use of the design structure of widely adopted models such as Nolan's Stage of Growth Model, Crosby's Grid, and Capability Maturity Model (CMM). Only recently have there been some research efforts to standardize maturity model development. We also identify three dominant views of maturity models and provide guidelines for various approaches of constructing maturity models with a standard vocabulary. We finally propose using process theories and configurational approaches to address the main theoretical criticisms with regard to maturity models and conclude with some recommendations for maturity model developers.

This paper systematically reviews literature on maturity models in IS. The paper then identifies research gaps and proposes use of process and/or configurational theory to address these challenges. The findings revealed few important insights: (i) Most of the maturity models are predominantly conceptual in nature; very seldom do IS researchers use theories or empirical methods while designing a new maturity model, (ii) Critics and observers have strongly emphasised empirically validated dimensions and maturity stages, and (iii) the path to maturation (i.e. something better, advanced, higher) is assumed to be linear and forward moving (rarely regressing).

Paper II: A Methodological Demonstration of Set-Theoretical Approach to Social Media Maturity Models Using Necessary Condition Analysis (Lasrado et al. 2016)

In Proceedings of the 20th Pacific Asia Conference on Information Systems. PACIS 2016. Chiayi, Taiwan. (Co-Authors: Ravi Vatrapu & Kim Normann Andersen)

Despite being widely accepted and applied across research domains, maturity models have been criticized for lacking academic rigor, especially methodologically rigorous and empirically grounded or tested maturity models are quite rare. Attempting to close this gap, we adopt a set-theoretic approach by applying the Necessary Condition Analysis (NCA) technique to derive maturity stages and stage boundaries conditions. The ontology is to view stages (boundaries) in maturity models as a collection of necessary condition. Using social media maturity data, we demonstrate the strength of our approach and evaluate some of arguments presented by previous conceptual focused social media maturity models.

This paper systematically describes the different components constituting a maturity model. The paper then conceptualizes stage boundaries as necessary conditions,

demonstrates the application of Necessary Condition Analysis (NCA) on a social media maturity dataset (dataset 1). The findings from this paper provided me with the required tools to move forward and write Paper III.

Paper III: A Set Theoretical Approach to Maturity Models: Guidelines and Demonstration (Lasrado et al. 2016)

In Proceedings of the 37th International Conference on Information Systems. ICIS 2016. Dublin, Ireland. (Co-Authors: Ravi Vatrappu & Kim Normann Andersen)

Maturity Model research in IS has been criticized for the lack of theoretical grounding, methodological rigor, empirical validations, and ignorance of multiple and non-linear paths to maturity. To address these criticisms, this paper proposes a novel set-theoretical approach to maturity models characterized by equifinality, multiple conjunctural causation, and case diversity. We prescribe methodological guidelines consisting of a six-step procedure to systematically apply set theoretic methods to conceptualize, develop, and empirically derive maturity models and provide a demonstration of its application on a social media maturity data-set. Specifically, we employ Necessary Condition Analysis (NCA) to identify maturity stage boundaries as necessary conditions and Qualitative Comparative Analysis (QCA) to arrive at multiple configurations that can be equally effective in progressing to higher maturity.

This paper proposed STAMM for empirically designing maturity models. Building on paper II, it conceptualizes stage boundaries as necessary conditions, then conceptualised stage characteristics in terms of configurations using QCA as the primary method (Ragin 2008). By combining NCA and QCA the paper demonstrated empirically the existence of multiple paths to maturity. At the time of writing this paper, it was the first attempt to combine both NCA and QCA in one study and the first one to apply set-theoretic approaches to maturity model design. This paper also provided IS researchers with a six-step procedure (STAMM) with detailed guidelines to systematically apply this approach.

Paper IV: Whose Maturity is it Anyway? The Influence of Different Quantitative Methods on the Design and Assessment of Maturity Models (Lasrado et al. 2017)

In Proceedings of the 25th European Conference on Information Systems (ECIS), Guimarães, Portugal, June 5-10, 2017. Co-Authors: (Ravi Vatrappu & Raghava Rao Mukkamala).

This paper presents results from an ongoing empirical study that seeks to understand the influence of different quantitative methods on the design and assessment of maturity models. Although there have been many academic publications on maturity models, there exists a significant lack of understanding of the potential impact of (a) choice of the quantitative approach, and (b) scale of measurement on the design and assessment of the maturity model. To address these two methodological issues, we analysed a social media maturity data set and computed maturity scores using different quantitative methods prescribed in literature. Specifically, we employed five methods (Additive, Variance, Cluster, Minimum Constraint, and RASCH) and compared the sensitivity of measurement scale and maturity stages. Based on our results, we propose a set of methodological recommendations for maturity model designers.

This research in progress paper identified the different quantitative techniques employed to calculate maturity. This paper provides a review of all the quantitative techniques employed for maturity model research and provided me with an opportunity to assess if these techniques could be employed to uncover multiple paths to maturity. We were also able to establish that the choice of quantitative technique does have an impact on the final maturity assessment results. This paper also resulted in adding the validation step to the STAMM six step procedure.

Paper V: Set-Theoretic Approach for Uncovering Prior Research Claims on ITIL Maturity

Under Review at AIS Transactions on Replication Research Journal (Single-Author).

This paper replicated and extended a study on ITIL maturity conducted in 2009 (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b). This conceptual replication tested the same research propositions on the original dataset, but using a different meta-theory and method. At the same time, this paper cleaned the original dataset further and improved the validity of the findings. This replication paper argued for use of multicondition analysis techniques over single condition analysis so as to provide a holistic understanding of the phenomenon being investigated. In particular, it employs a configuration theory perspective of ITIL maturity and uses the set-theoretic approach to test its associations with conditions like business benefits, business-IT alignment, ITIL processes implemented, and challenges for their implementation. The paper concludes with a few reflections on the lessons learnt during the process and implications for replication studies in general.

This paper supports the demonstration of STAMM in a different empirical setting. The dataset here is very different from the first empirical study (paper II and III). The survey is explorative in nature and poses its own set of challenges, especially with regards to arriving at macro conditions and the process of calibration for QCA. Within the context of this PhD thesis, one important factor is the role of the researcher during calibration and interpretation of the results. I always kept one of the authors informed about the choice I made and evaluated the final results.

Paper VI. Combining Partial Least Squares with Set Theoretic Methods: A Demonstration in the Context of Maturity Studies.

Unpublished Work: First draft.

(Co-Authors: Ravi Vatrapu, Till Winkler, Jochen Wulf)

This paper endeavors to contribute to the recent literature on set theoretic methods, in particular fuzzy-set QCA, by assessing whether it can be usefully combined with other statistical techniques. Specifically, the study applies Necessary Condition Analysis (NCA), fuzzy-set QCA (FsQCA) and regression based methods (PLS-SEM) to examine to strengths and weaknesses of a combined methodological approach in understanding the conditions associated with IT service management (ITSM) maturity. The study uses a recent survey dataset studying ITSM maturity of 127 organisations. The comparison between the methods demonstrates that each has its merits and drawbacks, but combining them leads to more insightful results and findings.

This final paper is yet another demonstration of STAMM. However, in this case the owners of the dataset were from the stream of IS behavioural research (Wulf et al. 2015) and were interested in combining STAMM with regression based methods like PLS-SEM to test the association of contextual factors with ITSM maturity. In order to address these needs, I combined redesigned STAMM to accommodate PLS-SEM and uncover insightful results and findings from their dataset.

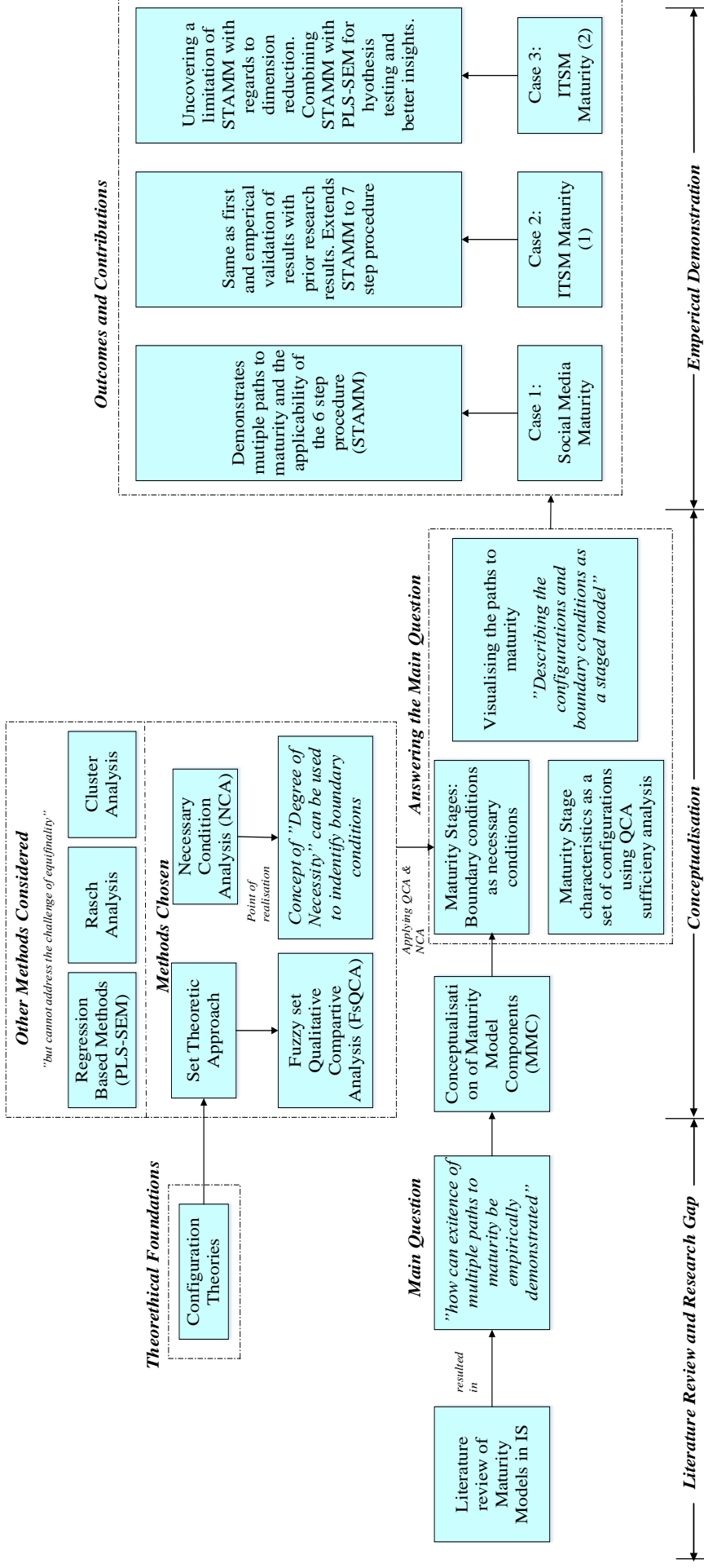


Figure 4: Timeline of the Thesis Process (how the study came about).

2. Philosophy of Science

“Adopting a particular paradigm is like viewing the world through a particular instrument. Each reveals certain aspects, but each is blind to others” (Mingers 2001)

All scientific research is based on implicit and/or explicit philosophical assumptions (paradigms or world views) about the world. These paradigms (Mingers and Brocklesby 1997) or worldviews (Creswell 2013) influence and drive both the research process and its outcomes. Social science research in general, and Information systems (IS) research¹⁹ in particular can be classified by four paradigms as shown in table 3. These research paradigms are grouped depending on a particular combination of philosophical assumptions covering, for example, “ontology, epistemology, axiology, and methodology” (Creswell 2013; Fitzgerald and Howcroft 1998; Mingers 2001). While Ontology focusses on the nature of things (what is reality), epistemology is concerned with the means by which we gain knowledge (how do we know reality). The methodology is the procedure or process to acquire this knowledge (what is assumed to exist) using “methods and techniques” for gathering and analysing data. Finally, axiology describes the relevance and rigor of the research conducted.

Table 3: Four worldviews (Creswell 2013; Creswell and Clark 2007).

	Post-Positivism	Constructivism	Advocacy	Pragmatism
Ontology	Singular reality	Multiple realities	Political reality	Singular, Multiple
Epistemology	Distance Impartiality	Closeness	Collaboration	Practicability
Axiology	Unbiased	Baised	Biased, negotiated	Multiple stances
Methodology	Deductive	Inductive	Participatory	Combined
Methods	Quantitative	Qualitative	Qualitative	Both

While many scholars have conceptualised these worldviews with rigid borders, some multi-method advocates (e.g. Mingers 2001, Venkatesh et.al 2013) have argued for the

¹⁹ Information systems research is mostly dominated by two worldviews: postpositivist and constructivist.

need to transcend these boundaries to address specific research questions. Mingers (2001) infact argues against the common belief that research methods are bound to particular worldviews and states that worldviews “are simply constructs of our thought, to hold that the world must actually conform to one of them is to commit the epistemic fallacy”. In this PhD thesis, I subscribe to this view and adopt the research philosophy of pragmatism²⁰ and argue for this position below.

Singular and Multiple realities: First, looking at the central theme of this PhD i.e. maturity models are positioned as pragmatic tools, with many scholars (Becker 2011; Mettler and Rohner 2009; Van Steenberg et al. 2013) considering them as design artifacts. Most IS researchers understand maturity models (MM) as practical tools (chapter 3) with maturity as a measure to benchmark, compare or simply speculate the evolution of an entity or object. In other words, the use of the term maturity is done in a comparative sense; for example, to immaturity (it’s like I am older than you, hence more mature). This understanding of maturity positions a researcher measuring maturity as a realist²¹. However, some researchers (Andersen and Henriksen 2006; Henriksen et al. 2004) have argued that using the term immature in relation to object under maturation is somewhat vague. In this PhD thesis, I use the fuzzy-set QCA to conceptualize the vagueness associated with maturity. By doing so, I acknowledge that the measure of maturity is relatively or comparatively better than immaturity and is fuzzy in nature; but so are all the measurements in social science (Ragin 2008). This is in line with the post-positivistic thinking that (i) there is a singular reality of what maturity is, but (ii) such understanding is always already a partial understanding of reality. As a pragmatist, while I subscribe to the worldview that the measure of maturity is objective and repeatable, there are multiple realities associated with the state of maturity i.e. objects mature differently; and groups of objects can have different pathways to maturation. Furthermore, as pragmatist, I do not object to both: (i) maturity measurement can happen through self-assessments, wherein the researcher acts an outsider and (ii) the researcher or a third-party consultant visits the organization and measures its maturity against a defined maturity model. In the latter, the distance

²⁰ John Dewey was a leading proponent of pragmatism. “For Dewey laws are not universal and immutable, solely waiting to be discovered. Instead they are more or less useful generalizations that work in a certain situation until they are found faulty and the search for new ones begins again” (Velástegui 2016). One could argue maturity models fit consistently with this thought; as they are situated at a certain point in time and become obsolete as soon the object becomes irrelevant (fades out or replaced by something new).

²¹ Realist: Belief that external world consists of pre-existing hard, tangible structures which exist independently of an individuals cognition (Fitzgerald and Howcroft 1998).

between the researcher and research situation is minimal, unlike a post-positivist who emphasizes on distance and impartiality.

Practicability: Second, the main objective of this PhD study was to design a systematic modelling procedure (artifact) with guidelines that could account for “equifinality” in the design of maturity models. The subsequent objective was to adapt this artifact to fit other situations that a maturity model researcher would encounter. In order to achieve those objectives, I followed a design science approach which situates itself in a pragmatic research paradigm (Hevner 2007). Moreover, during the “design search process”, I looked beyond the epistemological debates about reality, and focused on finding solutions for the problem at hand. In the process, I attempted to transcend the methodological boundaries²² by subscribing to the principle of methodological pragmatism (Howe 1988) and multi-method pluralism (Mingers 2001; Mingers and Brocklesby 1997). My worldview was that of a pragmatist wherein my research design and operational decisions were solely based on ‘what works best’ when answering the class of questions being investigated (Creswell and Clark 2007). This can be observed in the design search process; wherein I explore the possibilities of using different methods and techniques with varying underlying assumptions in order to find a solution to my problem (paper III), and in paper VI wherein I demonstrate the benefits of a multi-method approach.

Combined, multi-method approach: Third, the core of STAMM (artifact) is Fuzzy-set Qualitative Comparative Analysis (Fs-QCA)²³, which positions itself as a method that bridges qualitative and quantitative research approaches (Ragin 2008). QCA is also understood as a mixed or multi-methods research approach (Olsen and Nomura 2009), that has both inductive and deductive elements in its research approach (Schneider and Wagemann 2003; Wagemann and Schneider 2010) that was initially developed and used only for case study research N (<30). However, scholars (Fiss 2011; Greckhamer et al. 2013) have developed strategies for its application to moderate N (>50) and large N (>300) datasets too. The proponents of QCA (Fiss 2011; Ragin 2008b; Wagemann and Schneider 2010) argue that one of the core feature of QCA is “qualitative interference”, wherein the researcher is allowed to interfere with the analytic process; boolean minimization process with his/her inputs. According to

²² The “design search process” was completely pragmatic; I was looking for theoretical and methodological solutions to accommodate multiple conjunctural causation (chapter 3.3), while handling multiple cases or samples (N>50).

²³ QCA combines strengths of both qualitative and quantitative techniques, but in principle is closer to case-oriented techniques. QCA produces modest generalizations, and requires an ongoing dialogue between data and the researcher, be it case-oriented knowledge and/or theoretical knowledge (Rihoux and Ragin 2008)

its makers (Ragin 1987; Ragin 2008a), this input is based on in-depth knowledge of the cases that are being analysed and/or theoretical knowledge based on researchers expertise. Therefore, unlike traditional quantitative approaches (e.g. using regression), at an epistemological level, QCA tries to bridge the objectivist-subjectivist dichotomies (Rihoux and Ragin 2008), while leaning towards either sides depending on the research design and data at hand. With moderate or large N studies, QCA leans more towards the objectivist side, as the researcher cannot maintain close proximity with his/her cases, and with small N, QCA would employ a more subjectivist perspective (Greckhamer et al. 2013). In all the three demonstrations used for this PhD study, I lean slightly towards a objectivist side as my contact with the cases (organisations) was limited. All of my set-calibrations were based on my assessment of data at hand (objective & subjective at the same time), theoretical inputs from existing literature (similar to Fiss (2011), Liu et al. (2017)), and inputs from complimentary methods like Necessary Condition Analysis (NCA).

Data Collection: The use of surveys for data collection in Information Systems (IS) is mostly associated with positivist/post-positivist worldviews with emphasis on objectivity, generalizability and repeatability. The survey samples are expected random, large and more representative, so that results can be generalized to larger populations (Fitzgerald and Howcroft 1998). Although the data used in all three demonstrations comes from surveys, the main focus has been to uncover the configurations from the collected data and showcase them as multiple paths to maturity. However, dataset 1 (paper III) and dataset 3 (paper VI) both did not have enough cases for analyzing very high maturity using QCA. Going by positivist thinking, the right strategy would be increase the overall sample size. However, since QCA as a technique was initially developed as a case-based methodology for small or medium N, the proponents of QCA argue for purposeful sampling (Kane et al. 2014; Ragin 2008). Reflecting now, being a pragmatist I could have (atleast in the case of dataset 1) asked NBI to identify and contact organisations with very high social media maturity so as to enrich the dataset and get enough positive cases to uncover very high maturity configurations. Moreover, I could have also taken a mixed method approach and conducted in-depth case studies on some sample organisations identified with each of the maturity configurations. This would have definitely strengthened the results and provided stakeholders with case examples while discussing each of the maturity configurations.

3. Maturity Models in Information Systems (IS)

The purpose of this chapter is to review the theoretical foundations of this PhD thesis. This chapter serves as a synthesis of the literature on maturity models research (paper I and IV) and defines a maturity model within the context of this PhD thesis. The chapter also reviews existing quantitative methods that have been adopted for maturity model research.

3.1 What constitutes a Maturity Model?

In Information Systems research the term “maturity models” is associated with Capability Maturity Model (Paulk et al. 1993), Crosby’s Maturity Grid (Crosby 1980), and Nolan and Gibson (1974)’s stage of growth model. In particular, Nolan and Gibson (1974)’s stage of growth model has informed the design of several other maturity models (Pöppelbuß et al. 2011). Post the adoption of Capability Maturity Model (Paulk et al. 1993) and its variants like CMMI (2010), the publication amount of maturity-related topics has risen steeply. According to Wendler (2012), in 2009 and 2010 alone, approximately 62 academic articles were published of which 34 were new maturity models. In my literature review (paper I), I found over 600 articles published over the last 15 years. The focus of these maturity models is diverse, with topics ranging from software engineering (Spruit and Röling 2014), IT service management (Wulf et al. 2015), business process management (Van Looy 2013) and digital business transformation (Berghaus and Back 2016). As to the purpose of use, IS researchers have consistently argued that maturity models are meant to facilitate (i) self assessment or third-party assessment (also known as descriptive), (ii) benchmarking or comparison (comparative), and (iii) provide a roadmap for continuous improvement (prescriptive) (De Bruin et al. 2005; Pöppelbuß et al. 2011).

Definition: There are many definitions of “maturity models” in the extant literature²⁴ and a selection is listed below:

1. “Maturity models describe the development of an entity over time (Klimko 2001). They define simplified maturity stages or levels which measure the completeness of

²⁴ I collected this definitions by reviewing meta-research articles, especially literature reviews on maturity models by Wendler (2012), Pöppelbuß et al. (2011), Becker (2011), Mettler et al. (2010), De Bruin et al. (2005), etc. which in turn lead me to the original articles.

the analyzed objects via different sets of (multi-dimensional) criteria” (Wendler 2012).

2. “Maturity models basically represent theories about how organizational capabilities evolve in a stage-by-stage manner along an anticipated, desired, or logical maturation path” (Kazanjian and Drazin 1989; Pöppelbuß and Röglinger 2011; Solli-Sæther and Gottschalk 2010).
3. “it is a structured collection of elements that describe the characteristics of effective processes at different stages of development. It also suggests points of demarcation between stages and methods of transitioning from one stage to another” (Pullen 2007 as quoted in Wendler 2012)
4. “Maturity Models or correctly maturity assessment models – are a widely accepted instrument for systematically documenting and guiding the development and transformation of organizations on the basis of best or common practices” (Raber et al. 2012; Raber et al. 2013).
5. “Maturity models provide the constructs—in the form of descriptors or variables that characterize each stage—that organizations require to determine their level of progress. The general idea of maturity models is that such hierarchical progression is beneficial to organizations” (Pöppelbuß et al. 2011; Solli-Sæther and Gottschalk 2010).
6. “Maturity implies an evolutionary progress in the demonstration of a specific ability (related to people, processes or objects) or in the accomplishment of a target from an initial to a desired or normally occurring end stage” (Mettler et al. 2010).
7. According to Wendler (2012), many directly adopt the definition of the capability maturity model and replace CMM by the entity or object they are interested in measuring: “The CMM is a framework representing a path of improvements recommended for software organizations that want to increase their software process capability” (Paulk et al. 1993).

An overarching finding from analyzing these definitions (paper I) point towards three points of view (world views) when developing and using maturity models: (i) a life cycle or evolutionary perspective (Nolan and Gibson 1974), (ii) benchmarking or performance perspective (Crosby 1980), and (iii) best practice guide or certification perspective (Paulk et al. 1993). However, lately the demarcation between these three

perspectives has become thin and fuzzy. Currently most of the maturity models in academic literature follow the potential performance perspective instead of life cycle or evolutionary one (Wendler 2012) while using Nolan and Gibson (1974)'s model as a conceptual point of departure (see exhibit 1).

Exhibit 1: Use of Nolan's model by Damsgaard and Scheepers (1999)

“Our use of certain aspects of the Nolan model should be understood in the following context. First, although Nolan's model can be regarded as old and controversial, it remains **widely popular and used by both academics** and practitioners alike. This provides us with a well-established and **conceptually stable departure point**. Second, we specifically steer away from the controversial elements in Nolan's model, in particular its use of the computer budget as a surrogate. Instead, we **only use Nolan's stage descriptions** and rely on the S-shaped diffusion curve as a **general pattern to portray** the organizational pervasiveness of intranet technology in our proposed model. Finally, we **do not subscribe** to the evolutionist belief in the Nolan model that **integration will ultimately be reached**. Instead, we introduce an evolutionary perspective and propose that **each stage poses an existential crisis** that must be overcome in order to ‘survive’ and evolve to the next stage.”

The illustration of usage of Nolan's model (Exhibit 1) demonstrates how most of the IS researchers approach maturity model design. Today, IS researchers acknowledge that a well-defined “final” stage of maturity may not be reached ultimately, instead they use the maturity model as classification schemes and as a means for measuring capabilities (Andersen and Henriksen 2006) with each maturity stage focussing on potential improvements which occur by moving along. Therefore, in this PhD thesis, I subscribe to the definition provided by Becker et al. (2010):

“a maturity model consists of a sequence of maturity stages for a class of objects²⁵. It represents an anticipated, desired, or typical evolution path of these objects shaped as discrete stages”.

Although some maturity models might differ slightly from this explanation in terms of purpose of use, this definition by Becker et al. (2010) provides the best summary and

²⁵ These objects are organizations, processes, people, technology and so on. For example, in Damsgaard and Scheepers (1999)'s model intranet implementation in an organization is an object, while in CMM (Paulk et al. 1993) the object was software capability of on organization.

reflection of the current understanding of maturity models in the domain of Information Systems (IS).

For example, Damsgaard and Scheepers (1999)'s intranet implementation stage of growth model had four maturity stages (i.e. initiation, contagion, control and integration), with each stage described using seven characteristics and three existential crises. One such characteristic is "staff" which described the important role players within the firm such as senior managers, technical and organizational intranet champions, content providers, developers and users. Another characteristic was "skills" that described the capabilities of staff who are involved with intranet implementation and management. The existential crisis are subsets of these characteristics and describe certain scenarios to progress to higher maturity. In this model, the authors argue that the first existential crisis is the need for the intranet to be 'grabbed' by a sponsor and if this does not happen, then the intranet implementation will be limited and stuck in the initiation level itself. Similarly, for intranet implementation to progress to higher levels of maturity (i.e. control), a critical mass of both users and content on the intranet must be achieved, so that technology is self sustaining without the help of technology champions. Finally, to progress towards integration, the authors argue that intranet across the organization must be controlled and well managed, otherwise the growth of intranet would stagnate and maybe even regress to being considered an experimental technology. Studying this model in detail, one can easily notice the evolutionary perspective taken by the authors; with each maturity stage having characteristics that are superior to lower stages with some necessary criteria to ensure the objects survival in that particular stage. The intranet model is mostly descriptive with guidelines for implementing intranet within an organization and guidelines to manage challenges.

A second example is that of ITIL (also ITSM)²⁶ process maturity model. IT service management (ITSM) is a widely recognized approach among IT practitioners looking to organize IT processes and functions around customer-oriented units of delivery (Wulf et al. 2015). ITIL process maturity (e.g. ITIL V3) is measured based on 4 sub-capabilities with each describing a certain phase of the service lifecycle, namely service strategy, service design, service transition, and service operation. Each of these sub-capabilities include a total of 25 service processes. For example, service operations include 6 processes namely event management, incident management, request

²⁶ The term ITSM and ITIL are used interchangeably in academic literature (e.g. Paper V and VI). ITIL is the most widely used framework for ITSM. Here each of 26 service processes as well the

fulfillment, problem management, and access management. Similarly, strategy, design and transition have 5, 8 and 7 processes respectively. Wulf et al. (2015) measured the maturity of each of the 25 processes on a multi-attributive scale using the six CMM based process assimilation stages (1: none, 2: initial, 3: repeatable, 4: defined, 5: managed, 6: optimized), each with specific descriptions (Table 4).

Table 4. ITIL maturity stages²⁷.

Stage	Stage name	Description of the Stages
0	Non-existent	Management of processes is not applied at all
1	Initial/ad hoc	Processes are ad hoc and disorganized
2	Repeatable	Processes follow a standard, are documented and understood
3	Defined	Processes are documented and monitored for compliance
4	Managed	Management monitors and measures according to metrics established on the previous level
5	Optimized	Good practices are followed and automated

Wulf et al. (2015) uses 6 so called attributes (similar to characteristics in the previous study). One such attribute is tools and automation which “addresses the level of automation of the process, the tools which are applied to increase process efficiency and their level of integration” (Wulf et al. 2015). At stage 0 there are no tools and all activities are manual, while stage 5 describes end-to-end automation. The progression happens over 5 discrete stages as shown in table 4. The other attributes namely: awareness and stakeholder communication, plans and procedures, skills and expertise, responsibility and accountability, goal setting and measurement also progress through these 5 discrete stages. For assessing maturity, the authors propose organisations to take the lowest of the six process attributes with an intention of minimizing the possibility of overestimating their maturity.

Another popular example is the Capability Maturity Model (CMM) which has five discrete stages wherein increase in process capability of an organization progresses from a stage of being completely unsystematic and chaotic to a stage of being predictable and continuously improving processes (Paulk et al. 1993). Post the publication of CMM, many researchers and practitioners across multiple domains have

²⁷ The short description of stages are taken from Marrone and Kolbe 2011a, while Wulf et al. 2015 describes the same using longer sentences.

employed a similar design and proposed maturity models in the domain of business process management (Tarhan et al. 2016), IT management (Becker et al. 2010), business-IT alignment (Luftman 2000) and so on. A study of about 138 such articles has been documented in paper I. Based on this extensive study I developed my understanding of maturity models and using the operational definition borrowed from Becker et al. (2010), I argue that a typical maturity model is made of six core components: (i) maturity stages, (ii) conditions, (iii) path to maturity, (iv) stage boundaries, (v) boundary conditions and (vi) assessment of maturity as illustrated in figure 5.

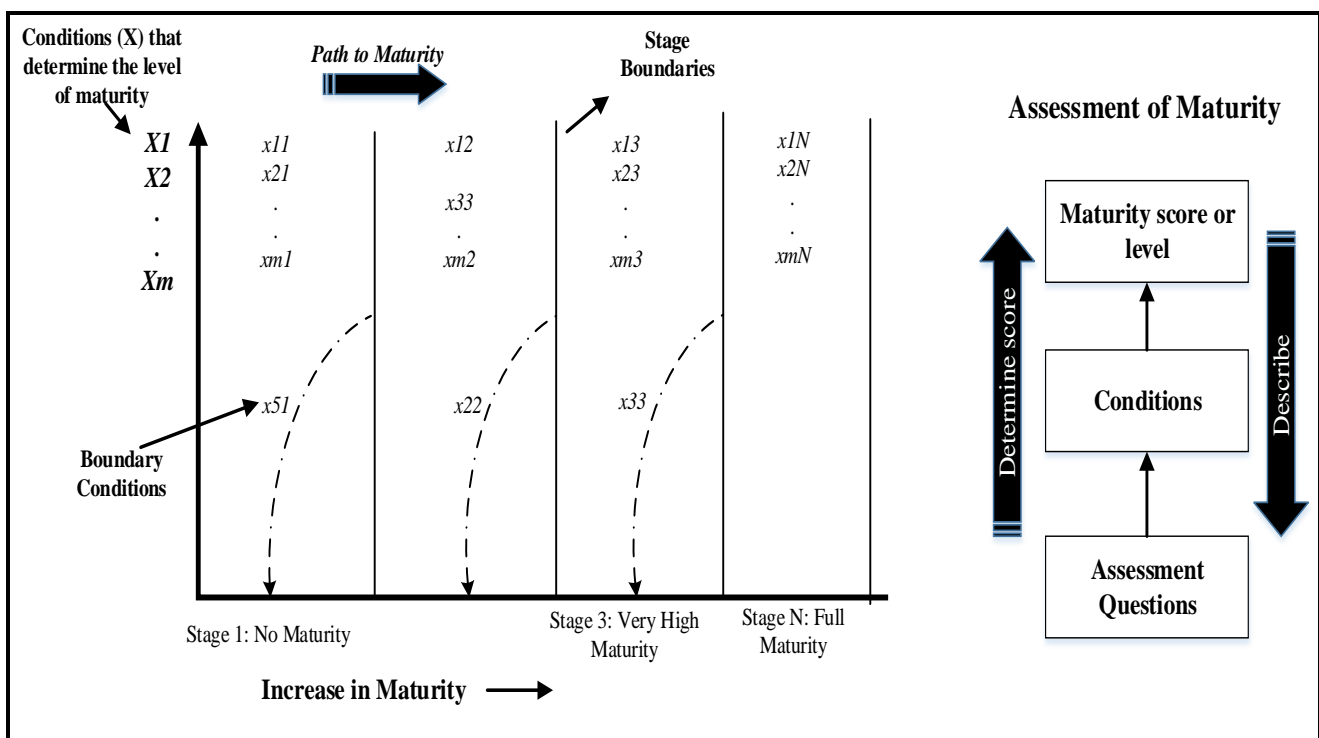


Figure 5: Core Components of a Maturity Model (Paper I, II and III).

1. **Maturity Stage** [Stage1... Stage n]: Also known as “Level” or “Maturity Score”. As described earlier, these stages typically are archetypal states of maturity of the entity that is being assessed. Each stage has a set of distinct characteristics that are testable (Nolan and Gibson 1974; Raber et al. 2012).
2. **Conditions** (X_{mn} , m factors and n stages): “Elements”, “Critical Success Factors”, “Dimensions”, “Factors”, “Enablers”, “Benchmark Variables”, “Attributes”, “Characteristics” and “Capabilities” are some of the other terms. Conditions describe multi-dimensional factors that decide the entity’s maturity stage. Each condition can be further classified into a number of sub-factors with specific characteristics at each stage (Raber et al. 2012).

3. **Boundary Conditions** [B1... Bn]: Also termed “Triggers”, ”Dominant Problems” (Solli-Sæther and Gottschalk 2010) and “Inhibitors”, “existential crisis” (Damsgaard and Scheepers 1999) are specific conditions that the entity has to satisfy in order to progress from one stage to another. These boundary conditions are subsets of the conditions; and can also be considered as the most important conditions for a particular maturity stage.
4. **Path to Maturity**: The path to maturation (i.e. something better, advanced, higher) is always linear, forward moving (rarely regressing), in which the entity improves considerably in terms of desired results i.e. capabilities, value creation, performance, etc. while traversing along this path (Duane and OReilly 2012; Solli-Sæther and Gottschalk 2010).
5. **Stage Boundaries**: These are boundaries (artificial) for the maturity stages. Although this component is very similar to the maturity stage itself, I have shown them as a separate component as it visualises a clear demarcation between stages.
6. **Assessment of Maturity**: Maturity assessment is the translation of a maturity model into quantifiable factors that can be measured. These assessments can be either qualitative (e.g. interviews)²⁸ or quantitative (e.g. questionnaires with Likert scales) (Raber et al. 2013). Quantitative assessments using likert scales are self reported maturity scores (someone from the organisation being assessed). For example, Marrone and Kolbe (2011a) uses a single-item measure for an overall ITIL maturity assessment²⁹, while Wulf et al. (2015) uses a multi-attributive scale (25 items) to assess maturity on an ITSM process level. Few other scholars (Joachim et al. 2011; Luftman 2000; Raber et al. 2013) assess maturity as a summation of the conditions themselves.

3.2 Quantitative Methods in Maturity Model Research

Based on a literature review of 138 articles on maturity models in IS (paper I) and supported by work of meta researchers (Pöppelbuß et al. 2011; Tarhan et al. 2016; Van Looy 2013; Wendler 2012), I was able to establish that maturity model design has mostly been conceptual. The empirical methods employed are mostly qualitative (e.g. case studies (N<5), interviews, Delphi studies). My literature review (paper 1) yielded

²⁸ Scope of this thesis is to look for assessment & benchmarking of atleast moderate N (>50) organisations. In such situations researchers can practically adopt only surveys.

²⁹ Single-item measure uses a single question to assess maturity.

a list of six quantitative methods (Table 5). While only Rasch analysis is employed in the design phase for constructing the maturity model from data collected via surveys, other techniques are employed in the assessment phase for calculating maturity scores and classifying the organisations. Finally, as expected, either a regression or correlation coefficient is used to establish positive associations between maturity score (or stage) and perceived benefits like performance, alignment, etc.

Another important observation made was that, all these techniques are in principle are variance approaches which means each condition, “whether standing alone as an additive contributor or combined multiplicatively, has a separable impact on the outcome; the extent of its impact is not lost in the intertwining of causes and conditions” (Mohr 1982). This means that conditions (X) have only one meaning over the course of time regardless of when the measurement occurred, hence making time ordering immaterial to the outcome (Ortiz de Guinea 2014; Van de Ven and Poole 1995). Therefore in essence the data collected is typically quantitative and cross-sectional. This is true in maturity model research, wherein quantitative assessments are mostly done by employing survey instruments. The data collection is mostly cross-sectional. Furthermore, the studies conducting assessment of maturity using surveys, also validated maturity using the same instrument. In fact, some scholars (Winkler et al. 2015; Wulf et al. 2015) use the same survey to determine predicted maturity (using conditions or contextual factors); provide a gap analysis between predicted maturity & actual maturity score; and finally assess the final expected outcomes (i.e. overall performance and alignment). All these surveys employ a 5-point likert scale or a 7-point likert scale to conduct their assessments.

Table 5. Quantitative Methods used in Maturity Models Research (from paper IV)

	Method	Assumptions	Application in Information Systems
Design (D)	RASCH: Rasch analysis or Item response theory (IRT).	Organizations with higher maturity have a high probability of successfully implementing capabilities, both easy and advanced. ³⁰ .	Rasch Analysis combined with Cluster Analysis was first used by Dekleva and Drehmer (1997) to empirically describe the evolution of the software development process in an organisation using capability maturity model (CMM) questionnaire.

³⁰ Similarly, lower maturity ones have a very low probability of implementing advanced capabilities. The term “capabilities” are bracketed as conditions in thesis. This method has since been applied by many scholars (Berghaus and Back 2016; Lahrman et al. 2011; Raber et al. 2012).

Assessment (A)	CLUSTER: 2 Step, Fuzzy Clustering (FC) or others: depends on data.	There are groups of organisations that are homogenous across a particular set of maturity capabilities.	Benbasat et al. (1980) uses cluster analysis for categorizing the companies in their study on organizational maturity on information system skill needs. Jansz (2016) adopts clustering to assess organisations' situational corporate collaboration maturity.
	ADDITIVE LOGIC (ADD): Summation or average of capabilities with or without weights for capabilities.	There is only one single linear path to higher maturity. The underlying assumption is that organisations with higher maturity will have implemented more number of capabilities.	Summation, simple average, and weighted average wherein the formulation of weights is arbitrary or non-empirical (Chung et al. 2017; Luftman 2000; Van Steenberg et al. 2013) are commonly used for maturity assessments. Empirically derived weights using SEM (Winkler et al. 2015) is rare.
	MINIMUM³¹ CONSTRAINT: (a) Statistical Squared Distance (SSD) (b) Euclidian Distance (EUC)	There is only one single linear path to higher maturity. The underlying principle is based on theory of constraints; the overall maturity is the level of maturity of the lowest capability.	There is only one instance each for application of SSD (Joachim et al. 2011) and EUC (Raber et al. 2013) who also prescribe a detailed 3-step procedure for SSD and EUC respectively. The only difference between the two methods is that SSD is weighted by the standard deviation at the capability level and EUC does not.
Validation (V)	VARIANCE: Regression, Correlation coefficients with tests for statistical significance.	Organizations with high maturity will also realise higher business benefits, performance and business value as compared to the ones at a lower maturity level.	Validating maturity using regression (Chen 2010; Joachim et al. 2011; Raber et al. 2013; Sledgianowski et al. 2006) or correlation coefficients (Marrone and Kolbe 2011) against self-reported maturity, perceived benefits or performance.

³¹ I named this technique "minimum constraint", however its principles are that of profile deviation analysis (PDA).

3.3 Can These Methods Demonstrate Multiple Paths to Maturity?

Now that I reviewed all the quantitative techniques employed for maturity model research (be it design, assessment or validation), I next assess if these techniques can be employed to demonstrate multiple paths to maturity (as this is the main objective of this thesis).

Rasch measurement theory represents a group of statistical models which are designed for the construction of interval-scaled measures of latent traits on the basis of dichotomously or polytomously scaled test instruments (Rasch 1993). Rasch analysis has been employed by many scholars (Berghaus and Back 2016; Dekleva and Drehmer 1997; Lahrman et al. 2011) as a useful analytical method to determine an evolutionary path to maturity and in tandem with cluster analysis to inductively determine maturity stages (Raber et al. 2013). The fundamental principle of Rasch analysis is that each condition can be ordered “according to this difficulty; and their difficulty sequence represents an empirically justified evolution” (Dekleva and Drehmer 1997; Lahrman et al. 2011). The algorithm then begins by counting the presence of conditions (i.e. probability of having successfully realized them) with an assumption that organisations with higher maturity “have a higher probability of having successfully implemented easy items” (Cleven et al. 2014). The algorithm then calculates two scores: one for the difficulty of realizing the conditions and one for the ability of the organisations to achieve them (Lahrman et al. 2011). Both these scores are on a single ordinal scale that represents the logit measure of each condition and organisation³², but no distinct maturity stages. The studies (Cleven et al. 2014; Lahrman et al. 2011) then employ cluster analysis on logit measure of items and set the anticipated number of clusters to five, citing previous maturity models. The main advantage of this method is that it can handle a large number of conditions. However there is a limitation that it is incapable of handling interrelationships between conditions and provides little insight into multiple paths to maturity. All the studies that have employed Rasch analysis have designed maturity models with only one path to maturity.

Cluster analysis on its own has also been employed to uncover groups of organisations that are homogenous across a particular set of conditions. E.g. (Jansz 2016; Lukman et al. 2011). It is employed as it can handle a large number of

³² For evaluating the quality of the model, two statistics termed ‘Infit’ and ‘Outfit’ are used. Both assess whether data that have been analysed (conditions as measured by items and organisations represented by survey participants) fit the expectations specified in the model. A five-point Likert scale is employed in all the studies instead of dichotomous scales. The BIGSTEPS software (Linacre 2009) is used by all studies used to calculate the Rasch item calibration.

conditions, but as it relies “quite heavily on subjective determinations”, such as number of clusters, the results are always subjected to additional scrutiny (Bedford and Sandelin 2015). Also, similar to Rasch analysis it is incapable of handling interrelationships between conditions and their relative contributions to the outcome. Finally, it does not provide insight into multiple configurations in each of the maturity stages and thus cannot uncover multiple paths to maturity from the data.

Multivariate Regression Analysis (MRA)³³ is another method that has been employed for both assessment and validation of maturity (table 4). With regards to modelling “equifinality”, there is abundant literature (El Sawy et al. 2010; Greckhamer et al. 2013; Vis 2012; Wagemann and Schneider 2010) as to why MRA is not a suitable method for this purpose. One of the main reasons is that MRA can model a “maximum of 2-way or 3-way interactions, as it is difficult to interpret higher order interactions” (Bedford and Sandelin 2015) and are “likely to result in multicollinearity” (Fiss et al. 2013). Therefore, when the number of conditions increase, it becomes practically impossible to account for such interactions. Moreover, regression emphasizes the average effects of one condition on another (Bedford and Sandelin 2015; Fiss et al. 2013; Thiem et al. 2016); which will ultimately lead to a unifinal additive solution explaining the outcome (i.e. maturity).

Based on the arguments presented above, I conclude that none of the existing quantitative methods employed for maturity model research can demonstrate multiple paths to maturity, especially when the data collected is cross-sectional. Throughout my literature review, I found only one article on maturity models (Kazanjian and Drazin 1989) using longitudinal data ($N > 50$). Understanding that most of the data collected would be mostly cross-sectional in nature, I expanded my search process beyond both variance and process approaches. This led me to configuration theory, Qualitative Comparative Analysis (QCA) and Necessary Condition Analysis (NCA) as discussed in the next chapter.

In the next chapter, I introduce configuration theory as a lens for maturity models. I also introduce QCA and NCA as methods to empirically demonstrate multiple paths to maturity. The chapter, then presents STAMM for designing maturity models and guides the readers towards paper II and III that explains all the guidelines to use STAMM. Furthermore, I present STAMM for hypothesis testing and guide the readers towards paper VI for the guidelines.

³³ PLS-SEM and other forms of regression analysis are also under this umbrella.

4. Design & Development of STAMM: Addressing Equifinality

The design search process lead me towards configuration theory and its potential to demonstrate multiple paths to maturity. The purpose of this chapter is to review configuration theory and associated set-theoretic approaches (methods). These are the kernel theories and foundations STAMM. In design science terminology, this chapter constitutes the design and development of the artifact itself as illustrated in the figure 6 below.

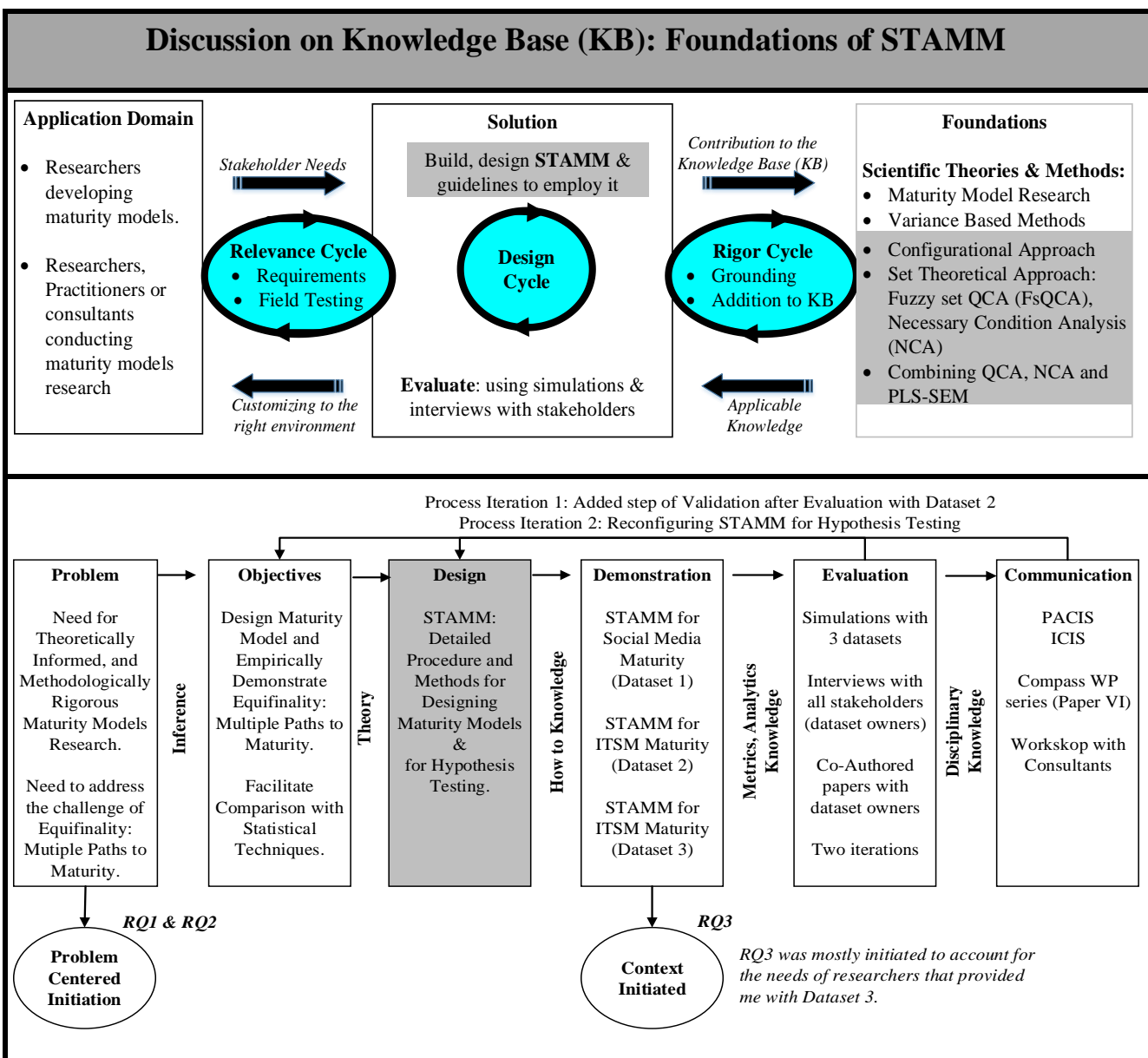


Figure 6: Design of STAMM. Adopted from Hevner et al. (2004) & Peffers et al. (2007)

The chapter is organized as follows. First, I discuss in detail configuration theory and present my arguments for considering it as my theoretical lens. Then, I present set-theoretic approach (STA) as a method for empirically demonstrating these configurations and propose STAMM for design maturity models and an extended version for hypothesis testing.

4.1 Theoretical Foundations: Lens of Configuration theory

In this section, I introduce configuration theory and state my arguments for using it as my theoretical lens. I then focus on the features that are relevant to maturity model design and conceptualise maturity models using the configurational approach.

IS research, till date has been mostly dominated by process and variance theories. While IS behavioural researchers mostly use variance theories and related methods like regression & PLS-SEM (Liu et al. 2017), process theories have been mostly used by researchers using qualitative methods (usually seen in maturity model research). Post the publication by Fiss (2007) in AMJ and the research commentary by El Sawy et al. (2010) in ISR, there has been some interest in configuration theory, both in business research and information systems. One of the main reasons for this increase is attributed to fact that configurational theories aid theory building as they focus attention towards equifinality i.e., a notion that “an entity can reach the same final state from different initial conditions and by a variety of different paths (my main motivation for using this as a theoretical lens to maturity models).

Configuration theory is basically concerned with explaining complexity involving multiple and interacting elements (Bedford and Sandelin 2015). The term “configuration” has its roots in the domain of strategic management and has many definitions. For example Meyer et al. (1993) defines it as a “multidimensional constellation of conceptually distinct characteristics that commonly occur together”. While for Miller (1996), a configuration is the degree to which an organization’s elements are orchestrated and connected by a single concept or theme. Other authors define a configuration as a classification system used to define sets of homogeneous entities, with an aim to provide rich description of the “ideal type” of organization (Doty et al. 1993). Since these definitions come from strategic management research, understandably the focus is on strategy constructs.

However, for my purposes, I move out of the strategic management tradition and use a more general definition advocated by (Liu et al. 2017; Ragin 2008; Rihoux and Ragin 2008) that a configuration

“is a specific set of conditions or causal variables that when working together, bring about an outcome of interest”.

I also define the terms that will be used throughout this thesis in table 6.

*Table 6: Terms and definitions*³⁴.

Term	Definition
Necessary Condition	A condition without which an outcome cannot occur, and other conditions cannot compensate for their absence (Dul 2016c; Goertz 2006; Ragin 2008), “X is a necessary condition of Y, if Y cannot happen without X”. A necessary condition, therefore is an antecedent condition to the outcome (Mohr 1982; Ragin 2008b).
Sufficient Condition	A condition (X) is sufficient for outcome (Y) if X implies Y or X is a subset of Y (Wagemann and Schneider 2010).
Core Conditions	Conditions that are necessary or sufficient elements of a configuration exhibiting the outcome of interest (Fiss 2007).
Peripheral Conditions	Conditions that exhibit necessary or sufficient elements but where the relationship with the outcome is weaker (Fiss 2007).
Configuration	A logical combination of conditions that when working together, brings about an outcome of interest (Liu et al. 2017), which is level of maturity for this study.

4.2 Arguments for Configuration Theory as Lens for Maturity Models

A review of the meta-research on configurations (Campbell-Hunt 2000; El Sawy et al. 2010; Fiss 2011; Liu et al. 2017; Pussayanavin 2013; Short et al. 2008), convinces me that a configuration is a scheme to describe firms according to their important “strategic” constructs and a theoretical proposition regarding the performance outcome of their “strategic designs”. This is very similar to what a maturity model is, and on closer examination, I find both similarities and differences between maturity models and configuration theories as listed in table 7. The purpose of table 7 is to compare the

³⁴ When authors used the terms “configurational theory” and “QCA”, they mean the same. Most authors, including Ragin (2008a), Fiss (2011) refer to the output of QCA (also called causal recipe, sufficiency solution, intermediate solution) as “a configurational solution”. Moreover Rihoux and Ragin (2008)’s authored a book called “Configurational comparative methods (CCM): QCA and related techniques”, thus prompting more authors to use the term configuration theory in their papers. Since field is new, there are many terms floating around.

similarities and differences between the concept of maturity model and configurations. Table 7 highlights four similarities and two differences, while arguing that, by employing a configurational view and the recent methodological advancements in configuration theories, maturity model can potentially address the challenge of modelling equifinality in the design of maturity models.

Table 7: Examples of similarities (S) & difference (D) noticed.

	Configurations	Maturity Models (from section 2)	
Purpose of use	“at their best are memorable, neat and evocative” (Miller 1996), while at their worst are little more than simplistic overviews that offer only a cursory look at organizations (Fiss 2007; Rich 1992).	Maturity Models also give simplistic reductionist view of a complex problem, thus creating awareness on competences , while offering a tangible way to look at organizations (Jugdev and Thomas 2002).	S
	“are more than anything products of inspired synthesis and a strong sense of conceptual esthetics” (Miller 1996)	In practice maturity models are strategic tools designed for driving change. Hence, there is strong sense of conceptual esthetics.	S
Design	“the elements or variables used to describe each type are shown to cohere in thematic and interesting ways that have important conceptual, evolutionary or normative implication” (Doty et al. 1993)	Maturity models in IS are both descriptive and prescriptive. As practice tools, they are highly normative in nature. Variables are used to assess the organisations’ maturity level. Each level has distinct characteristics of features.	S
Grouping	“are groups of firms sharing a common profile of organizational characteristics” (Ketchen et al. 1997) and usually used to classify “ideal types”	Even maturity models are expected to group similar group of organisations having similar characteristics.	S
Epistemology	“The assumption of equifinality is implicit in configurational theories because they identify multiple ideal types that maximize fit” (Doty et al. 1993), wherein equifinality means	Maturity models currently assume unifinality and single linear path to maturity. However this difference is “a feature	D

	an entity can reach the same final state from differing initial conditions and by a variety of paths (El Sawy et al. 2010; Fiss 2011)	and not a bug”. If one could adapt the notion of “equifinality” into maturity model design, then this could answer the research question in this thesis.	
	“follow combinatorial logic, with an assumption of assymetry” (Fiss 2011; Park and El Sawy 2013)	Most often than not the logic of determining maturity is through the process of aggregation. Hence the assumption is that of symmetry.	D

Another similarity between configurations (E.g. Miles-Snow’s typology, and Mintzberg’s organizational configurations) and maturity models (E.g. Nolan’s stage of growth, CMM) are that they are well accepted among researchers and practitioners alike. However, for all their theoretical attractiveness and practical applicability, until recently, most configuration theorists have provided only limited empirical support (El Sawy et al. 2010; Fiss 2007; Fiss 2011). This was mainly because of the limitations of existing methods to match the theoretical assumptions of the respective configurations (Fiss 2011; Greckhamer et al. 2013; Park and El Sawy 2013; Vis 2012). But, with the emergence of QCA, configuration theorists (Bedford and Sandelin 2015; Fiss 2011) have been able to address these empirical challenges. Moreover, these advancements are understood to have moved beyond conventional configuration theories into what El Sawy et al. (2010) conceives as a second generation of configuration theories.

Given the similarities between underlying principles of maturity models and configurations (Table 1), and the recent theoretical and methodological advancements in configuration theories, I see this as an opportunity to look at maturity models through this lens. In summary, the following are my reasons for choosing a configurational perspective:

1. Maturity Models research needs to address the notion of equifinality in their design. A configurational perspective has the potential to address this challenge.
2. Although differences exist (table 1), most of them are actually opportunities to conceptualise maturity models using a configurational perspective. For example, maturity model scholars adopt an additive and linear logic while determining maturity levels. If this assumption is changed to a combinatorial logic, then the challenge of empirically demonstrating equifinality can be addressed (see the section on conceptualization).

3. I argue that if multiple paths to maturity exists, then the object under maturation will provide evidence for existence of those paths. If I am able to indentify those diverse cases from the population, then I must be able empirically demonstrate its existence. The second generation of configuration theories provide me with the necessary tools (methods like QCA) to do so.
4. Maturity models researchers from a quantitative tradition mostly use cross sectional surveys (sample size $N > 50$). In my literature review of maturity models, I found only one study (Kazanjian and Drazin 1989) that used longitudinal data with a sample size greater than 50. Given the practical challenges of collecting longitudinal data, configuration theory gives me a lens and necessary tools to visualize multiple paths to maturity from cross-sectional datasets (especially surveys).

However, this second generation of configuration theory stands solely on the shoulders of *set-theoretic approaches*, in particular Qualitative Comparative Analysis (QCA) (Ragin 1987; Ragin 2008). Except for Fiss (2011)'s conceptualization of core and peripheral conditions, the rest of concepts, underlying principles terminologies and arguments are all borrowed from Qualitative comparative analysis (QCA)³⁵, and variants like temporal QCA (Caren and Panofsky 2005; Rihoux and Ragin 2008) which anchors itself as a configurational comparative method, consisting of both a research process and analytical technique³⁶, which I have discussed in detail in paper III (section 2.1).

4.3 Conceptualisation: Configurational Perspective to Maturity Models

Armed with the relevant terminologies (configuration theory), I now conceptualise a maturity model using the configurational perspective. I explain the process in three steps as illustrated in figure 7. Step 1 and step 2 are not sequential but parallel.

Step 1: Boundary Conditions as Necessary Conditions: Boundary conditions are necessary conditions; this means without satisfying the criteria set for these conditions, an entity cannot progress from a state of low maturity to high maturity irrespective of it satisfying all other conditions. These boundary conditions are compulsory pre-

³⁵ A review of QCA in IS is presented in appendix 1. This is important in the context of my PhD as my empirical datasets (Paper III, V and VI) are all moderate N surveys. Recent studies (Emmenegger et al. 2014; Fiss 2011; Liu et al. 2017) have advocated use of QCA for moderate ($50 < N < 300$) and large surveys ($N > 300$). This has captured the interest of IS quantitative researchers. Hence through a literature review of application of QCA in IS Behavioural research in particular, survey research in general, QCA is equally relevant for large N studies.

³⁶ For a detailed review of the definitions, please refer paper III and articles by (Fiss 2007; Fiss 2011)

conditions for increase in maturity. To elaborate I use the same example (chapter 3.2) of intranet maturity model (Damsgaard and Scheepers 1999). According to Damsgaard and Scheepers (1999), implementation and use of intranet in an organization passes through all the 4 maturity stages (i.e. intranet initiation, intranet contagion, intranet control, and intranet integration). Every maturity stage has a crisis (boundary condition). For example, active support of a technology champion is a boundary condition to progress from intranet initiation (stage 1) to intranet contagion (stage 2), and certain critical mass of intranet users is necessary to progress to intranet control (stage 3). By definition, these boundary conditions are nothing but “necessary conditions” (Dul 2016c) i.e. the absence of satisfying the minimum criteria to meet these conditions guarantees failure in terms of progression to the next stage of the maturity model³⁷. As illustrated in figure 7, there X1 is a boundary condition for high maturity stage and not for low maturity stage; this also means that is a core or peripheral condition for all the configurations in that maturity stage (i.e. its presence is mandatory in all configurations).

Step 2: From one set of characteristics for a maturity stage to many possibilities:

In short, I call this maturity stage characteristics as configurations. The traditional view of maturity models describes each maturity stage as having a set of distinct characteristics that are testable (Nolan and Gibson 1974; Raber et al. 2012). Most often than not, these set of distinct characteristics is one additive solution. In the intranet example, to be in stage 3 (intranet contagion) there are 9 conditions that an organisation must satisfy (and all have to be met); this is additive thinking. Instead, I propose a configurational thinking to stage characteristics; which means in Damsgaard and Scheepers (1999)’s model, for an organization implementing intranet to be in stage 3 (intranet contagion), it does not have to satisfy all the 9 conditions, provided it has met all the necessary (boundary) conditions to be in this stage 3. The organization now can satisfy fewer conditions and still be in that maturity stage, while being grouped together with similar organisations. Similarly there might be a group of organisations with different set of characteristics also in the same maturity stage. For example, in figure 3, high maturity stage has two such groups (3a and 3b). Both have two different set of characteristics, but have satisfied all the boundary conditions required for high maturity.

³⁷ Since maturity (Y) and conditions (X) are quantitatively measured in surveys, I can determine the degree of necessity of the condition (X) necessary to achieve certain level of maturity (Y). This can be achieved using Necessary Condition Analysis (NCA) which is discussed in methods section (for detailed guidelines and steps refer paper II).

Boundary Conditions as Necessary Conditions

1. X1 is necessary for High Maturity = X1 is a boundary condition for High Maturity
2. X2 is a boundary condition for Low Maturity
3. X3 is a boundary condition for Full Maturity
4. X4 is is a boundary condition for Low Maturity
5. X5 is is is a boundary condition for Full Maturity
6. Xn is a boundary condition for High Maturity

Maturity Stage Characteristics as Configurations

	No Maturity	Low Maturity			High Maturity		Full Maturity
	1a	2a	2b	2c	3a	3b	4a
X1	⊗			●	●	●	●
X2		●	●	●	●	●	●
X3	⊗	●	⊗		●	⊗	●
X4		●	●	●	●	●	●
X5	●			●	●		●
Xn	⊗	⊗	⊗	●	●	●	●

Process logic: Moving from one stage another through multiple pathways

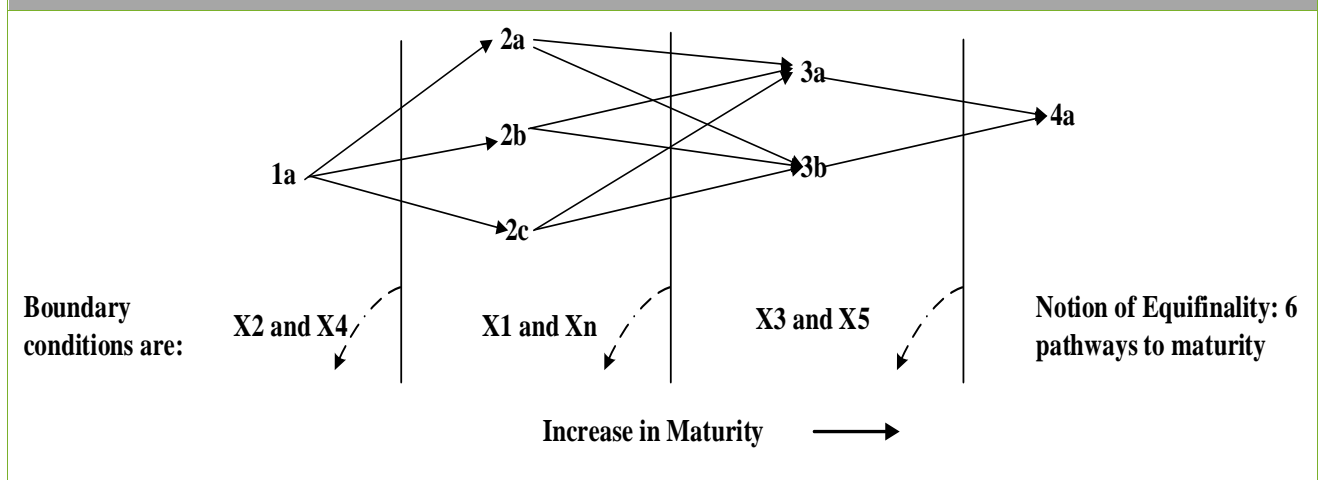


Figure 7: Conceptualising multiple pathways to maturity.

Step 3: From configurations to multiple pathways to maturity: The next logical step is to deduce multiple pathways from the configurations themselves. I do so by resorting to “process thinking” or “process logic” (Ortiz de Guinea 2014; Van de Ven and Poole 1995) for justifying the connection between configurations in maturity stages and the possible connections between them³⁸. By employing this thinking a total of six pathways to maturity can be realized illustrated in figure 7. For example, 1a-2a-3a-4a is one path, while 1a-2a-3b-4a is another.

Now that I have conceptualized a maturity model from a configurational perspective, in the next section, I present the set theoretic approach (STA) employed in this thesis as a method to empirically uncover these maturity stages and configurations.

4.4 Set Theoretic Approach (STA) to Uncover Configurations

Set theoretical approach (Ragin 2000; Ragin 1987; Schneider and Wagemann 2012) is characterized by three central attributes: *equifinality* (multiple pathways to the outcomes), *multiple conjunctural causation* (configurations of multiple causes rather than unicausal reduction), and *case diversity* (inclusive of both positive and negative outcomes). The above three characteristics make them strongly resonate with configuration theory (Fiss 2011; Liu et al. 2017) and provide researchers with an empirical tool kit to facilitate configurational analysis. Based on Smithson and Verkuilen (2006), Vatraru et al. (2016) highlighted key advantages of applying classical set theory (Kechris and Kechris 1995) in general and fuzzy set theory (Zadeh 1965) in particular to social science research:

- (a) *Set-theoretical ontology* (e.g. Crisp Sets, Fuzzy Sets) is well suited to conceptualize vagueness, which is a central aspect of many social science constructs. In the context of maturity models, I concur with Henriksen et al. (2004) that the concept of maturity is quite vague and somewhat fuzzy as compared to maturity in biology and thus set theory would be a suitable technique to conceptualize this vagueness.
- (b) *Set-theoretical epistemology* is well suited for analysis of social science constructs that are both categorical and dimensional. That is, set-theoretical approach is well suited for dealing with different degrees of a particular type on construct. In the context of maturity models, maturity is measured using variables that categorical and dimensional.

³⁸ I use the same logic that authors use while inferring from variance models. Variance models are “constructed by specifying relations between sets of variables, they rely on “process logic” dynamics to explain and justify such relations (Ortiz de Guinea 2014).

- (c) *Set-theoretical methodology* can analyze multivariate associations beyond the conditional means and the general linear models which allows for both quantitative variable centered analytical methods as well as qualitative case study methods. In the case of maturity models, this allows for both variable centered analytical methods like surveys as well as qualitative case studies.
- (d) *Set-theoretical analysis* has high theoretical fidelity with most social science theories which are usually expressed logically in set-terms. For example, maturity model stages like theories on market segmentation and political preferences are logically articulated as categorical inclusions and exclusions that natively lend themselves into set theoretical formalization.
- (e) *Set-theoretical approach* systematically combines set-wise logical formulation of social science theories. In the case of maturity models, it is possible to employ crisp set and fuzzy sets to derive data points for maturity variables. In this thesis, I employ the fuzzy set analysis to calibrate maturity variables (i.e. conditions).

Given the above advantages, applications of set theory to management science and IS research has steadily increasing over the last few years. Apart from use of simple Venn diagrams to visualize big social data (Jussila et al. 2016; Vatrappu et al. 2015), formalized applications of set theory in IS research is mainly attributed to the method called “Qualitative Comparative Analysis (QCA)” (Thiem and Dusa 2012) developed by Charles Ragin (Ragin 1987; Ragin 2008), a political scientist. Although developed initially by Ragin (1987) for qualitative case study researchers (medium sample size of $N < 90$), the proponents and supporters of QCA have since then argued about its unique advantages over regression-based approaches (Cooper 2005; Emmenegger et al. 2014; Wagemann and Schneider 2010) and its application for analysis of large-N datasets (Cooper 2005; Emmenegger et al. 2014). In the increasing adoption trajectory of QCA in social sciences (Thiem and Dusa 2012), three variants have surfaced: (a) crisp-set QCA (CsQCA), (b) fuzzy-set QCA (fsQCA) (Ragin 2008), and (c) multi-value QCA (MvQCA) (Wagemann and Schneider 2010), with a number of software tools supporting set-theoretical social science researchers (e.g. fs/QCA, Tosmana, R packages like QCA and QCAPro). Initially applied by a small academic community of sociologists and political scientists, this method has now been widely adopted for investigating typologies and configurations in the fields of management sciences (Fiss 2007), marketing (Tóth et al. 2015), engineering (Jordan et al. 2014) and very recently in the domain of information systems as shown in Table 8.

Table 8. QCA application in Information systems³⁹.

Topic, Authors, Outlet		Characteristics of the study	Software
User resistance to IT (Rivard and Lapointe 2012)	MISQ	Applied Cs/QCA on 137 episodes of resistance to IT and evaluated both single and multiple conditions for sufficiency.	(Ragin and Davey 2014)
Electronic Service Failures (Tan et al. 2016)	MISQ	Applied CsQCA in a unique way along with chi-square test to detect correlations between indicators (i.e., e-commerce service failures) and outcome variables (i.e., disconfirmed expectancies).	(Ragin and Davey 2014)
IT Strategy (Levallet and Chan 2015)	ICIS	Applied CsQCA on survey responses (100) using factor scores to calibrate sets.	(Ragin and Davey 2014)
IT project management (Poon et al. 2011)	ECIS	This study measured the importance of conditions (Goertz 2006) by employing necessary and sufficient condition logic to rank the importance of conditions in IT project management.	None

4.4.1 Qualitative Comparative Analysis (QCA)

QCA as a set-theoretic method models associations (in terms of necessity and sufficiency) as subset or superset relations. As stated earlier, QCA focusses on arriving at complex patterns in terms of equifinality, multiple conjunctural causation and asymmetry (Fiss 2007; Ragin 1987; Ragin 2008; Wagemann and Schneider 2010). QCA is designed to compare multiple cases in terms of complex configurations of attributes and outcomes (Bedford and Sandelin 2015). The ultimate goal of QCA is to *analyze set-theoretic sufficiency relations* (Ragin 1987). QCA is grounded in the analysis of set relations, not correlations (Ragin 2006; Ragin 2008) and hence unlike conventional statistical methods it does not measure the average effect of an increase or decrease of one variable on another. Instead, QCA analyses complex connections between attributes and outcomes in terms of set relationships (Bedford and Sandelin 2015). As such, identifying the necessary and sufficient conditions form the core of

³⁹ Full list of studies using QCA published in IS prominent IS outlets provided in Appendix 1 (section 7.1).

this set theoretic approach. In its simplest form one can either use Euler/Venn diagrams, cross-tabulation techniques or in the case of continuous membership scores (fuzzy set), the X-Y plot is adopted (Goertz 2006; Mahoney and Vanderpoel 2015; Wagemann and Schneider 2010) as shown in figure 8.

First, let's look at "necessary conditions", as without them the outcomes cannot occur, and other conditions cannot compensate for their absence (Dul 2016c; Goertz 2006; Ragin 2008), "X is a necessary condition of Y, if Y cannot happen without X and is denoted by $X \leftarrow Y$ ". A necessary condition, therefore is an antecedent condition that is a superset of the outcome (Mohr 1982; Ragin 2008). As shown in Figure 8, depending on the set formulation (i.e. crisp or fuzzy), in a perfect world one could detect a necessary condition, just by inspecting the Euler/Venn diagram or the X-Y plot. With both crisp and fuzzy sets (Figure 8: 1st and 3rd column - 1st row), the necessary condition is represented as a superset relation and indicated as $X_i \geq Y_i$ (X is a superset of Y). Another way of identifying necessary conditions is using cross-tabulation (lower left corner of Figure 8). A test for necessity essentially requires us to look at only the first row (cells 1 & 2), while cells 3 and 4 are completely irrelevant. The test for sufficiency however proceeds from the *observation of some condition(s) X to the observation of the outcome Y* (Thiem and Dusa 2012; Wagemann and Schneider 2010), i.e. "X is a sufficient condition of Y, if X implies Y or X is a subset of Y and is denoted by $X \rightarrow Y$ ".

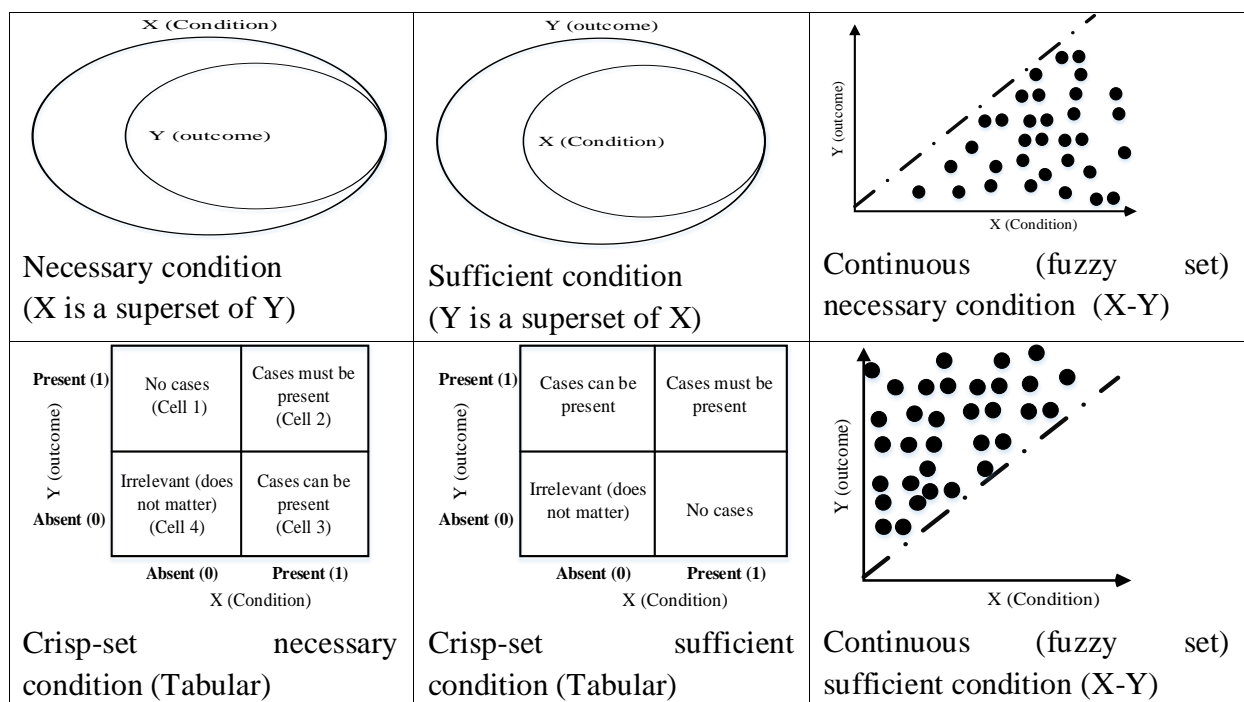


Figure 8: Necessary and Sufficient Conditions.

While the method of single condition analysis (binary variables in Figure 8) is of analytical value, according to Ragin (2006), examining relations between binary variables “*might be considered adequate as a descriptive starting point, but this approach is too crude to be considered real social science*”. Moreover, social sciences in general (Mohr 1982) and information systems in particular deals with what are INUS conditions: *insufficient but non-redundant part of an unnecessary but sufficient condition* (Ortiz de Guinea 2014). QCA scholars have argued the advantages of set theoretical methods in explaining INUS conditions and developed a number of measures (Goertz 2006; Ragin 2006) and guidelines (Wagemann and Schneider 2010) to make analysis of complex causations possible. These include guidelines to develop a truth table, calibration of original data to sets, measures of *consistency*, *coverage*, (Ragin 2006) and also some diagnostics to detect logical contradictions and paradoxical relations (Bedford and Sandelin 2015; Thiem and Dusa 2012). These measures are similar to adjusted R^2 or p-value in conventional statistical analysis and are well established in the set theoretical social science literature. QCA uses crisp and fuzzy set algorithm (Quine-McCluskey) combined with qualitative counterfactual analysis to arrive at the final Boolean solution i.e. intermediate solution (Ragin 2008b; Thiem and Dusa 2012; Wagemann and Schneider 2010). In this thesis, I have employed the fuzzy set QCA as it allows assignment of memberships scores (also known as calibration) to conditions and provides flexibility to express degree of presence and absence (i.e all levels of maturity), as compared to CsQCA wherein a condition is either fully present or fully absent (i.e. mature or immature).

4.4.2 Necessary Condition Analysis (NCA)

QCA has a number of advantages as discussed above, but has some limitations in detecting complex necessary conditions, especially single necessary but not sufficient conditions (Vis and Dul 2016). Moreover, calibration of the original data into set-memberships and the construction of the truth table forms the core of QCA. This calibration involves transforming the original dataset, and some scholars (Goertz 2006; Vis and Dul 2016) point to the possibility of this step leading to a failure to detect some of the necessary conditions. NCA addresses this problem and is a method for identifying necessary conditions in data sets (Dul 2016c) be they categorical or continuous in nature (Vis and Dul 2016). As a method, NCA addresses the limitation of identifying necessary conditions as well as measuring the degree of necessity (more details in the analysis section). Unlike QCA, which requires calibration of the dataset to set memberships, NCA measures the degree of necessity in terms of effect size (i.e. area of emptiness in the top right corner of the X-Y plot in Figure 8).

A comparison of the results of NCA and QCA (presented in paper III and VI) highlighted the advantages of NCA in identifying more single necessary conditions than QCA, and above all calculating the degree of necessity as a clear advantage (Dul 2016c). Secondly, at this point in time, literature on maturity models lacked an empirical technique to define the number of maturity levels or stages. In all previous studies that inductively designed maturity models (Cleven et al. 2014; Raber et al. 2012); the process of arriving at the number of maturity stages was completely arbitrary. Most studies (Duane and O'Reilly 2012; Lahrman et al. 2011) either cited previous maturity models and argued that 4 to 5 maturity stages was the most appropriate number. Some others (Karkkainen et al. 2011) argued that they have made this choice as the cognitive capacity of users is limited to 4 to 7. In order to make selection of number of stages less arbitrary and empirically founded, I adopted the concept of “degree of necessity” (Dul 2016c) from NCA to make an informed choice regarding the number of maturity stages (i.e. explained in detail in paper II and III).

In line with the recent methodological advancements in set theoretic social science discussed above, I complement QCA with NCA and derive the set theoretic approach for maturity models in the next section.

4.4.3 Set Theoretic Approach for Maturity Models (STAMM)

In this section, I present STAMM as a procedure model and method for maturity models design. STAMM is employed to empirically uncover maturity stages and stage configurations that were conceptualised in section 4.3. The procedure for STAMM logically follows the three steps proposed on section 4.3 (figure 3). The elements of STAMM for designing maturity models (figure 9), are informed by (a) detailed review of guidelines and procedures for developing maturity models (Becker et al. 2011; Mettler et al. 2010; Solli-Sæther and Gottschalk 2010), (b) guidelines for standard practices in QCA (Ragin 2008; Fiss 2011; Goertz 2006; Thiem and Dusa 2012; Wagemann and Schneider 2010), and (c) guidelines for NCA (Dul 2016a; Vis and Dul 2016). The steps along with detailed guidelines are provided in paper III (§ 4). The detailed steps to conduct NCA and derive boundary conditions are provided in both paper III (§ 4) and paper II (§ 6.1). Hence the following explanation in this section is very brief.

STAMM begins with defining the research context of interest. The problem setting and intention for design and development should be clearly stated; scope, targeted audience and main stakeholders for the maturity model clearly defined. Furthermore, it is

important to formulate maturity; define the “object” whose maturity is being measured and the measures reflecting its maturity. Further, describe the conceptual model in detail, explain the conditions (X) and their relationship with maturity of the object (Y). Next, explain the measurement instrument; for example, Marrone and Kolbe (2011b) used surveys for data collection with 503 respondents (self assessment) rating their perceived ITSM maturity level from 1 to 5 (paper V). The data collection plays a crucial part; while self assessment surveys help to increase the number of cases (N), thus increasing the probability for more diversity among cases, data collection via third party assessment might yield a smaller N, but thick description and understanding of maturity.

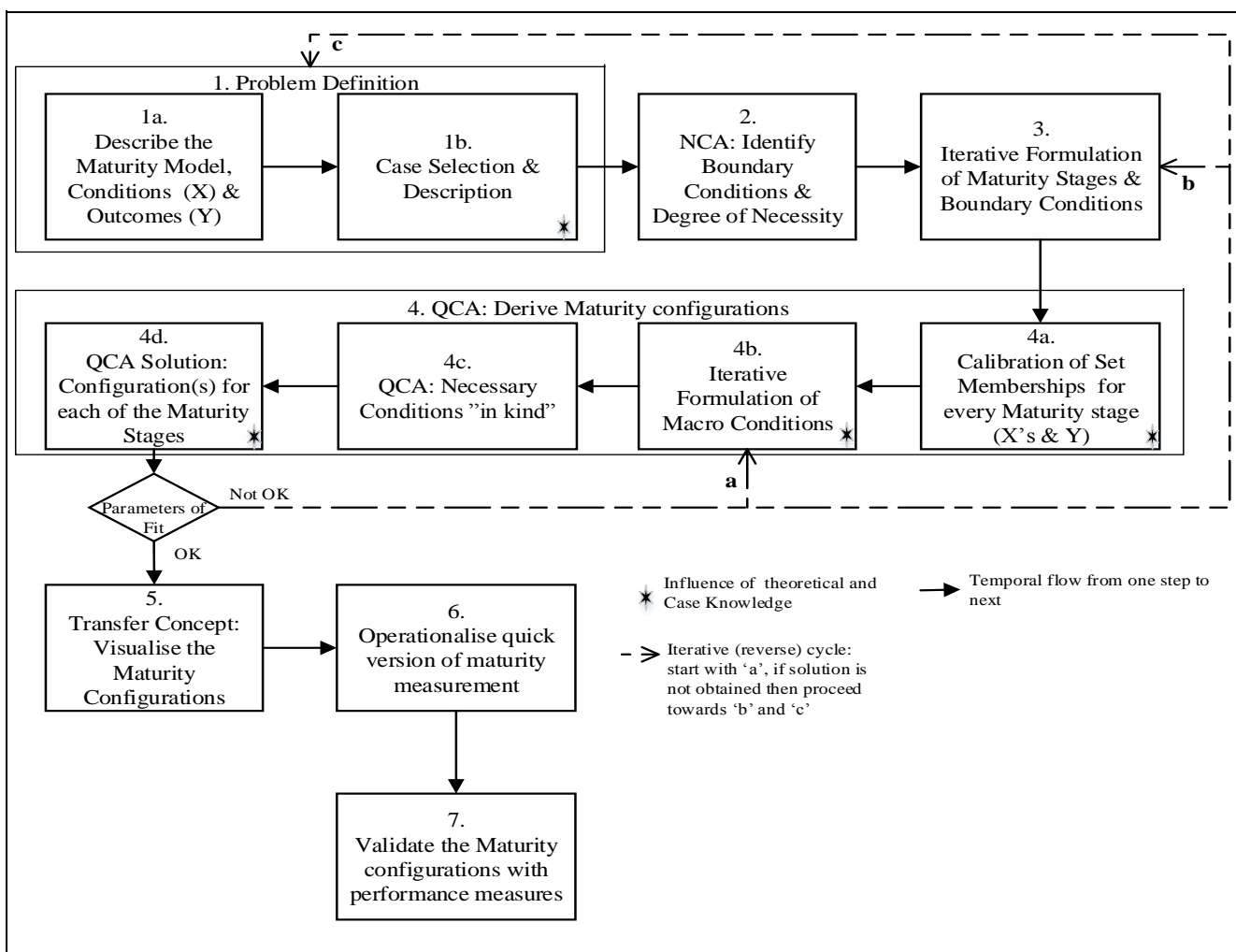


Figure 9: STAMM for design of Maturity Models.

Since the core of STAMM’s analytical procedure is QCA, one important meta-requirement for its application is to ensure case diversity, so that the analysis leads to multiple configurations or pathways to maturity. The final step (validation) was added in the second iteration of STAMM as illustrated in figure 9. This step was realised

during the analysis for dataset 2, wherein each maturity configuration is validated by testing its relationship with business outcomes (paper V: § 4.3). This is under the assumption that organizations with high maturity will also realise higher business benefits (performance) as compared to the ones at a lower maturity level. Although this assumption has been critiqued and challenged (Mullaly 2014), as stated in paper IV, it is the most employed quantitative method for validation.

4.4.4 Combining STAMM with PLS

The elements of STAMM for hypothesis testing (figure 10) is informed by STAMM for designing maturity models, and literature on application of FsQCA while combining them with statistical techniques (Fiss et al. 2013; Greckhamer et al. 2013; Levallet and Chan 2016; Schneider and Rohlfing 2013; Vis 2012). While methodological purists (Katz et al. 2005; Lee 2008) argue against this (i.e. regression analysis and QCA differ epistemologically), multi-method researchers (Fiss 2007; Fiss 2011; Levallet and Chan 2016; Vis 2012) find value in combining them. In fact, the most influential article applying QCA in business research (Fiss 2007; Fiss 2011), applied both QCA and statistical techniques (e.g. clustering, and regression) on a moderately large N^{40} survey. These multi-method advocates (Fiss et al. 2013; Vis 2012) argue that the epistemological differences are an advantage rather than a drawback as it allows for a distinct view of the problem being investigated. This formed the underlying principle for this version of STAMM, which is re-configured as a hypothetico-deductive procedure as illustrated in figure 9.

This re-design was done so as to meet the requirements of maturity model researchers interested in combining STAMM with PLS. While most of the procedure is similar to figure 8, the only difference is use of factor scores for calibration of sets. Specifically, the PLS factor scores use to calibrate fuzzy-set memberships and then apply NCA is employed on these membership scores. This is mainly done to facilitate comparison with PLS-SEM results. Following the work of Fiss (2011), Levallet and Chan (2016) and others, I have employed mean of PLS factor scores (i.e. 0) as the midpoint or cross-over point (Paper VI: : § 4.2.1). However, the researcher using STAMM should choose the inclusion, exclusion and midpoint depending on data at hand and case knowledge. Furthermore, linear transformation with entry into set membership as

⁴⁰ While there are no concrete set of rules, QCA scholars refer to sample size $(N) < 30$ as small, and anything above that as large N . However, recently some scholars have started differentiating between very large sample size (> 300) and others, while referring to sample sizes between 50 and 300 as moderately large N .

minimum and full membership coded as maximum of the PLS scores is calculated to identify single necessary conditions using NCA in accordance with recommendations by Dul (2016a). Finally, all the results are compiled and discussed (step 5 & 6) as illustrated in paper VI (§ 4).

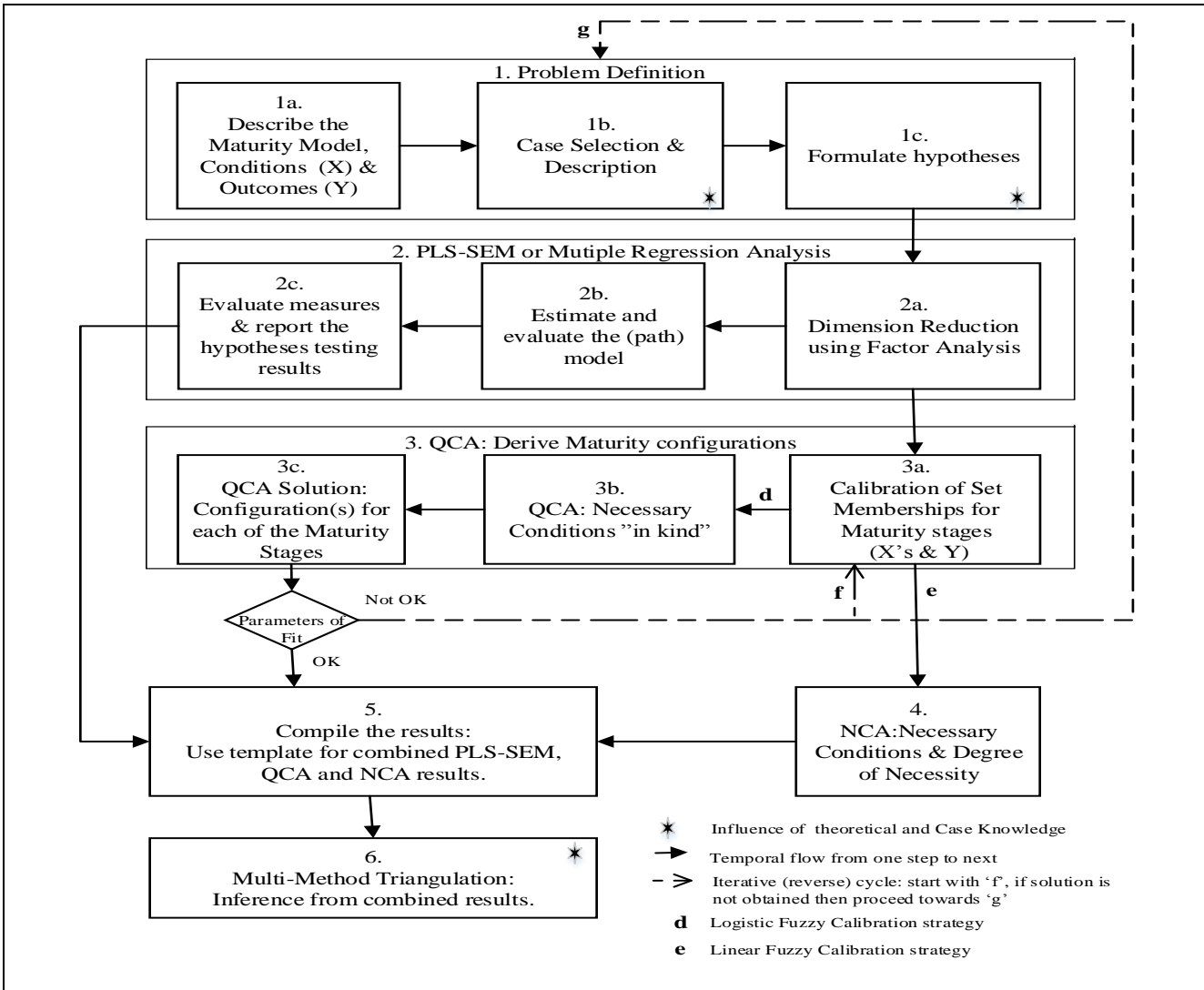


Figure 10: Combining STAMM with PLS-SEM.

As presented in paper VI, in the context of ITSM maturity, STAMM is combined with PLS-SEM to corroborate at-large statistical associations (as for employee capability and system criticality, H3 and H4), explain and unveil details regarding at-large non-significant statistical associations (as for innovative IT strategy, H1), relativize at-large statistical associations (as with SP size, H5) and contradict statistical associations (as with the Industry variable, H6). In the next chapter, I present the demonstration and evaluation results of STAMM using dataset 1 and dataset 2. STAMM for hypothesis testing is also demonstrated and evaluated using dataset 3.

5. Demonstration & Evaluation of STAMM

The purpose of this chapter is to briefly present the results from the demonstration and evaluation (figure 11) of STAMM using real world datasets (Paper III, V, and VI). The evaluations take place using survey datasets and discussion of the results with the stakeholders (i.e. dataset owners).

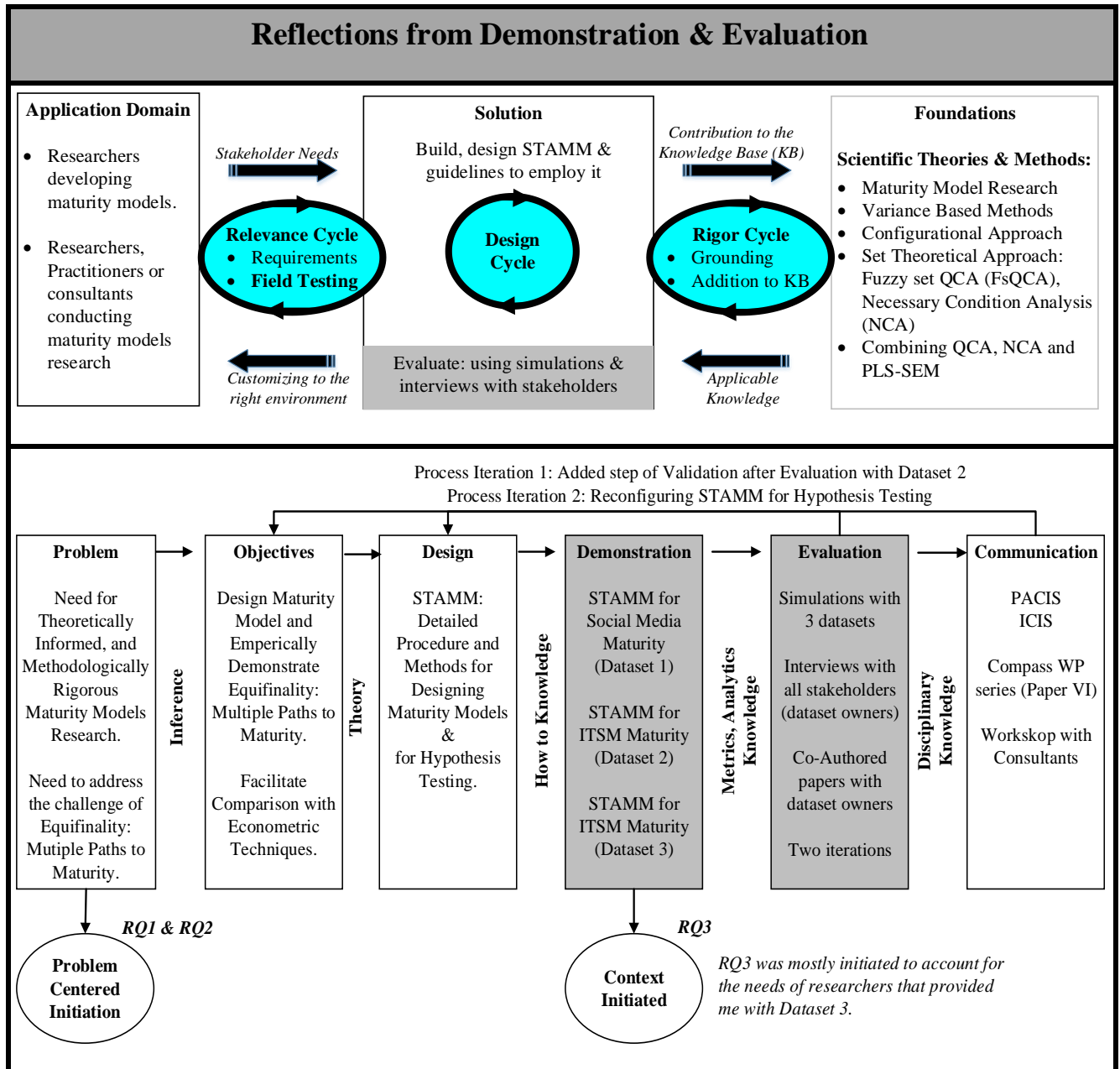


Figure 11: Demonstration and Evaluation. Adopted from Hevner et al. (2004) & Peffers et al. (2007)

Finding empirical datasets to demonstrate and evaluate the potential of STAMM to deliver results was equally important in the context of this PhD thesis. A key component to this demonstration was first the availability of suitable datasets and consequently my accessibility to these datasets. The first requirement was that the dataset must have a minimum sample of 50 cases. Secondly, the data must be a numeric format to allow an analysis i.e. if qualitative data, then it must have been already coded. Finally, the data must have either maturity or a suitable proxy for maturity as the dependent variable. While I had direct access to dataset 1 (NBI social media maturity dataset), based on the three requirements, I succeeded in acquiring two more datasets.

5.1 Results from Demonstration and Evaluation

Papers III, V and VI present the applications of STAMM using three different datasets. The role of these papers is to demonstrate the successful application of STAMM. The evaluation of STAMM using the three empirical datasets i.e. social media, ITIL and ITSM maturity is illustrated in table 9.

Table 9: Evaluation of STAMM.

	Social Media Maturity (NBI)	ITIL (Marrone and Kolbe 2011b)	ITSM (Wulf et al. 2015)
Data from	Consultancy	Researcher	Researcher
Year	2015-2016	2016-2017	2016-2017
Survey	networkedbusiness.org	Research-papers	Research-papers (itil.selfsurvey.org)
Conceptual Model Data Collection	Data was collected between Nov 2015 to March 2016. Full access to the data, from data collection to analysis of it. The NBI questionnaire is not founded on strong theoretical arguments, but mostly industry inputs (similar to	Data was collected in April and May 2009. I had no influence, but the data collection is documented in two research papers. Relevant research on ITIL (ITILV2/3) are foundations for the survey. Questions are explorative in nature.	Data was collected in 2014-2015; the survey is still live. I had no influence, but the data collection is documented in two research papers. Relevant research on ITSM (ITILV3) are foundations for the survey. The survey

	consultancy models like Deloitte, and IBM). Although I was doing the data analysis for NBI, I had almost no say in the construction of the benchmarking survey.	The survey was not fully designed for conventional statistical analysis. The researcher then employed univariate methods to establish associations.	designed for conventional statistical analysis. The authors employ PLS-SEM to study relationships between ITSM maturity and contextual factors.
Demonstration	Paper III	Paper V	Paper VI
Evaluation	Workshop with NBI; The face Validity of the social media maturity model.	Skype discussion with the author. Comparison with prior research papers (Paper V) and internal validity established against business benefits.	Continuous interaction with the author (Till Winkler). Evaluation of results through informal conversations and co-authoring a paper (paper VI).
Proof-of-Concept Proof-of-Value	NBI considered the concept of multiple paths to maturity viable and closer to reality than the current understanding of a single linear path to maturity. However due to lack of funding, and their attention drifting to newer projects, NBI did not employ the proposed social media maturity model. Instead they are employing STAMM on a completely new context: Happiness of	Employing STAMM on the dataset, I was able to go beyond the univariate methods and uncover ITIL maturity configurations. Furthermore, my analysis corroborated the findings from the original research by Marrone and Kolbe (2011a) and Marrone and Kolbe (2011b). Employing STAMM, I was able to uncover additional insights and extract more value from the given dataset, which	STAMM for hypothesis testing was employed. STAMM uses the benefits of PLS-SEM, in particular dimension reduction; helps with macro conditions. STAMM was able to uncover additional insights and extract more value from the given dataset, which is both proof of concept and value. The face validity of the results was established with

	Danish workers; which can be considered as proof of value.	is both proof of concept and value.	owners of the dataset. They then co-authored paper VI with me, which can be considered as proof of value.
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5.2 Reflections & Methodological Limitations

There were a number of methodological and practical challenges faced during these three demonstrations. These problems ranged from data collection to method specific challenges like choosing the right calibration functions, ceiling line techniques and cut off points. The methodological reflections have contributed to developing and refining STAMM through two iterations as illustrated in figure 10.

Reflection 1: Purposeful Sampling or Random sampling

First, let's start with data collection and sampling. In order to use STAMM, apart from specifying and articulating the conditions (X) and outcomes (Y), the strategy chosen for data collection has a significant impact on further analysis and subsequently the results. As discussed in paper III (§ 4), while random sampling is recommended for conventional statistical analysis, the proponents of QCA argue for purposeful sampling (Kane et al. 2014; Ragin 2008). However, many multi-method researchers (Fiss et al. 2013; Levallet and Chan 2016; Liu et al. 2017) have successfully employed QCA on data collected using random sampling strategy. The debate around the right strategy for sampling is more practical than epistemological in nature. QCA scholars mostly argue for purposeful sampling so that the truth table is populated enough with empirical data (case diversity) and thus ensure that the analysis leads to multiple configurations. This has practical implications; for example, dataset 3 (paper VI) did not have enough cases for analyzing very high maturity using QCA. According to practical recommendations by QCA scholars (Kane et al. 2014; Ragin 2008), the owners of dataset 3 will have to contact only companies with very high maturity and ask them to take the survey in the future so that the maturity configurations for very high maturity stage could be established⁴¹. However, by doing so, owners of dataset 3 will not be able to apply inferential statistics (level of significance, degree of confidence, etc.) on the future dataset. To avoid this, one strategy is stick to random sampling, hoping that companies

⁴¹ Similar is the case for dataset 1, wherein lack of enough positive cases was the reason for not deriving the very high maturity configurations.

with very high maturity will use their survey instrument in the future. This is one major concern that came about in the demonstration and evaluation phase. At this point in time, this PhD thesis does not have a concrete solution for this dilemma, except for some practical advice. However, this is a matter of debate for both QCA and regression methodologists in the future.

Reflection 2: Cross-over points - Implications of Fuzzy membership as 0.5

The cut off points for fuzzy set memberships is a special point in between full membership and full non-membership, also known as the crossover point. This is usually a midpoint (and is coded as 0.5), especially when the direct method of calibration is employed. QCA scholars (Ragin 2008; Wagemann and Schneider 2010) have argued that a membership score of 0.5 implies a case with the maximum ambiguity and thus runs the risk of being dropped out of the QCA sufficiency analysis.

For example, in the case of social media maturity configurations (Paper III: Figure 7), only 16 of the 81 cases were used to arrive at the final solution. However, post writing this paper and closely following some of the best practises employed by the QCA community (Cooper and Glaesser 2011; Fiss 2011), I observed that the midpoint (fuzzy set cross over point) is usually coded as 0.51 instead of 0.5. While the authors do not explicitly state arguments for this arbitrary choice, the basic idea is to include as many cases as possible in the truth table analysis. I believed that this fact would have implications on the final analysis of paper III⁴² and hence set out to test that by recoding fuzzy set cross over point fro 0.5 to 0.51. This re-analysis led to some improvements for STAMM, that have been discussed here.

In the first analysis (paper III with 0.5), the final truth table for high maturity stages had only 12 rows (16 cases used). In paper III, I argued for a frequency N=1 with an inclusion criteria of 0.75 and arrived at the solution. However, after recoding the midpoints to 0.51, and using an inclusion criteria of 0.75 with frequency of N=1 a total of 52 rows (from all 81 cases) were being included in the truth table analysis. Furthermore, N=2 resulted in 15 rows (with 48 cases) and N=3 resulted in 8 rows (34

⁴² The differences between the two results were minor; very high maturity produced the same result, while implications on low maturity was minimal. However, high maturity stage had some minimal differences in maturity configurations. But overall the solution and interpretation remained comparable with the one presented in paper III.

cases)⁴³. Following the steps listed in STAMM, the high maturity configurations using recoded data were extracted and are presented in figure 12.

The new QCA results (recoded as 0.51) with an inclusion criteria of 0.75 and frequency of N=2 provide five configurations for high maturity stage (2a, 2b, 2c, 2d, 2e), while frequency of N=3 provide three configurations (3a, 3b, 3c). Furthermore, the effects of increasing the inclusion criteria to 0.8 is also checked as shown in figure 12.

Conditions	(N=3, INCL=0.75)			(N=2, INCL=0.75)					(N=2, INCL=0.8)		
	3a	3b	3c	2a	2b	2c	2d	2e	2a(0.8)	2b(0.8)	2c(0.8)
Technology											
Social media Presence											
Extent of Use	FUE	●	●	●	●	●	●	●	●	●	●
Ressource (FTE)											
Skills	SK	●	●	●	●	●		●	●	●	●
Metrics	M	⊗	⊗			⊗	⊗	⊗		⊗	●
Management											
Encouragement to use	MUS	●	●	●	●	●	●	●	●	●	●
Increased Investment	INV	●	●	●	●	●	●	●	●	●	●
Culture											
Employee Driven	EEC	●					●	●			●
Structured	PSC		●	●			●	●	⊗	●	⊗
Explorative	NSC	●	●	●	●	⊗	●	●		●	●
IT Policy											
IT security Policy											
BYOD	ITP			⊗	⊗	●	●		●	⊗	
Provide devices											
Consistency	0.86	0.83	0.78	0.79	0.80	0.78	0.73	0.74	0.86	0.87	0.86
Raw Coverage	0.20	0.25	0.30	0.29	0.13	0.36	0.10	0.21	0.15	0.17	0.07
Unique Coverage	0.03	0.02	0.10	0.04	0.06	0.05	0.01	0.01	0.11	0.13	0.03
Overall Solution Consistency		0.80				0.73				0.87	
Overall Solution Coverage		0.37				0.48				0.33	

Figure 12: High Maturity Characteristics for recoded data (dataset 1).

Comparing the different solutions in figure 12, while some minor changes were observed with regards to number of subsolutions (configurations), the overall interpretation using any of the results would remain the same. Therefore, in order to choose the best solution, I explore the deviant cases and attempt to determine the importance of each of the subsolutions relative to each other. For example, lets take configuration 3a to illustrate the point. Cases with membership score of 0.5 or greater

⁴³ As with our previous analysis (in the paper), the directional expectations or counterfactuals were also coded as present (positive or +1) as all the conditions (X) are expected to be present in high maturity stage.

in configuration 3a are as follows: CA6 (0.82,0.99), CA84 (0.55,0.79), CA12 (0.51,0.43), CA13 (0.51,0.95), CA22 (0.51,0.15), CA25 (0.51,0.43), CA28 (0.51,0.95), CA38 (0.51,0.43), CA40 (0.51,0.99), CA45 (0.51,0.43), CA69 (0.51,0.95), CA73 (0.51,0.79)⁴⁴.

It is very clear that most of the membership scores are on the borderline of 0.51, while CA22 (0.51,0.15) actually contradicts the outcome (high maturity). Moreover, 4 cases (i.e. CA12, CA25, CA38, and CA45) can be classified as borderline deviant cases too. Using the ratio of number of deviant cases against total number of cases, I compare different QCA solutions. The logic is simple; smaller the ratio better is the solution. Using this criteria, the three configurations (3a, 3b, 3c) produced with inclusion criteria of 0.75 and N=3 is chosen as the final solution.

However, there arises a question; how many deviant cases are acceptable and to what degree. First, in the case of configuration 3a, a total of 5 out of 12 (i.e. 42%) are deviant cases of which one case (i.e. CA22) fully contradicts the outcome. Second, the majority of cases contributing to the final solution are borderline with membership scores of 0.51. This is mainly due to the fact as majority of the cases had variables with a fuzzy score of 0.51, thus resulting in it driving down the solution membership score. While, I did not find standards or defined benchmarks, QCA scholars have employed strategies ranging from dropping variables and cases to re-defining the set memberships (re-calibration).

While this exercise of re-calibration is not undertaken for dataset 1, this learning from applying STAMM on dataset 1 was used to improve and update STAMM. The summary of the reflection is as follows: (i) Do not drop cases that are considered neutral (i.e. calibrated as 0.5). If majority of the conditions explaining maturity is coded as neutral (set membership of 0.5), the re-define and re-calibrate the conditions, and (ii) Look at the deviant and borderline cases carefully and do not only rely on ready measures of consistency and coverage. This learning and reflection from this dataset resulted in the creation of the % error measure, that was implemented in dataset 3 (paper VI). The concept behind this measure is to persuade researchers using STAMM to relook at the results and re-calibrate data if necessary. This is added to the parameters of fit so to ensure that impact of deviant cases is known and understood before interpreting the QCA results.

⁴⁴ Here CA6 represents case number 6, while 0.82 represents the configuration 3a membership score of case 6 while 0.99 represents the high maturity membership score of case 6.

Reflection 3: Questions regarding arbitrary benchmarks for QCA

Most QCA scholars (Bedford et al. 2014; Skaaning 2011; Wagemann and Schneider 2010) advocate standards of best practice and have set certain *benchmarks*. As best practice, researchers employ a minimum consistency of 0.9 for necessary condition analysis and at least 0.75 for sufficiency analysis. I also adopted this best practice in my analyses⁴⁵. However, I found no papers in QCA literature that provide any methodological or theoretical grounds for these difference in benchmarks. I concur with Thiem (2017) that both necessity and sufficiency are mirror images of each other and the difference in these benchmarks will need more explanation by QCA methodologists. Therefore adopters of STAMM will have to keep themselves updated on the latest research with regards to selection of QCA benchmarks.

Reflection 4: Inclusion and exclusion criteria for set memberships

The inclusion and exclusion criteria is a matter of intense debate in QCA (Vis 2012). For example, in dataset 3, the set boundaries are formulated based on factor scores, which might be debated by methodological purists. The formulation of sets are done in accordance with direct calibration and I have followed strategies employed by other scholars (Fiss 2011; Levallet and Chan 2016; Liu et al. 2017). However since the debate on this is still ongoing, researchers employing STAMM must be aware of this debate of using factor scores for creating set memberships.

Reflection 5: Balancing the number of conditions (X)

The computational limitations of existing softwares restrict number of conditions to 13. For example, the libraries on R like QCA and QCAPro cannot handle more than that. Moreover, the data required (number of cases) increase exponentially as the number of condition increase. In order to cover all empirically possibilities, the researcher has to collect 2^n cases, where n is the number of conditions. This means if you have 6 conditions, then you need 64 cases, while 8 conditions would mean 256 cases. However, QCA has steps like counterfactual analysis and truth table inspection to account for missing combinations. One strategy employed in the three demonstrations is reducing the number of conditions into higher level macro conditions. For example,

⁴⁵ With regards to coverage, there are no methodological/theoretical arguments for a minimum value.

while analysing dataset 1, I reduced the number of conditions (X's) by either dropping or merging conditions (employing AND, OR, any other set logical operations) as prescribed by Ragin (2008). I dropped a condition called digital strategy (DS) by arguing that it did not contribute to the final solution, proposed a macro condition "FUE" by combining common necessary conditions and employed Ragin (2008)'s colligation strategy to arrive at another macro condition "IT Policy (ITP)". Another example is dataset 3, wherein I utilized the advantages of PLS-SEM analysis to reduce the number of conditions. PLS-SEM is a very mature method for data analysis and there are multiple well-documented measures and strategies available to the researcher for dimension reduction (e.g. factor analysis) and finding the best fit model with the most important and relevant conditions (automated search algorithms measuring BIC, AIC and stepwise regression)⁴⁶. QCA on the other hand is still in its nascent stages and measures for dimension reduction are yet to be developed. QCA researchers are expected to arrive at the most important conditions (macro conditions) solely based on theoretical or case knowledge (both paper III and V). This puts a researcher wanting to do explorative or quasi-experimental research⁴⁷ using QCA on a back foot. In paper VI (dataset 3), while I use QCA and NCA to corroborate PLS-SEM findings, looking from another angle, PLS-SEM actually subverts QCA's weakness. In the absence of solid analytical dimension reduction techniques in QCA, PLS-SEM factor analysis actually makes QCA possible.

Reflection 6: Sensitivity of NCA to outliers and measurement errors

A major limitation of NCA is that it "may be more susceptible for sampling and measurement error than traditional data analysis approaches" (Dul 2016c). The main reason for this is the way the ceiling techniques work. The ceiling lines are drawn using only a small proportion of the observations in the sample, therefore making it very vulnerable to outliers, particularly the ones close to the left corner of the X-Y plot. While Dul (2016c) evaluating the cases closer to the ceiling line, this will be a difficult task with large N studies. While, in all the three datasets, I had sufficient number of cases around the ceiling line, researchers using NCA should be aware of this challenge.

Reflection 7: Replication research in Information Systems (IS)

⁴⁶ In this study, I have used both factor analysis and automated search algorithm as discussed in paper VI (section 4).

⁴⁷ I refer to survey research with multiple indicators and 7 constructs.

In an attempt to acquire datasets for demonstration of STAMM, I contacted several maturity model researchers, but succeeded in acquiring only two datasets with a success rate of less than 10%. While many chose not to respond, others that did stated that they had either lost it or currently did not have access to it. Although not everyone formally gave me a reason, I speculate that their unwillingness to share could be due (i) contractual obligations, (ii) fear of original analyses being questioned, and (iii) lack of proper data storage practices. Although this PhD study is not about replication studies, I have documented this as an important observation. Replication is something that the Information systems (IS) should strongly think about.

Reflection 8: Skills and asymmetric thinking

A researcher employing STAMM should have a high level of declarative and procedural knowledge of Qualitative Comparative Analysis (QCA) and Necessary Condition Analysis (NCA). A shift from linear and symmetric thinking is a challenge for traditional IS behavioural researchers and I noticed during my evaluations with owners of dataset 3. Therefore, I argue that a researcher looking to employ STAMM should accept the fact configurational logic is built on asymmetric thinking of causality unlike traditional correlational techniques (Regression, SEM, etc). Moreover, the researcher must possess analytical skills with R. This because most of the software tools available for both QCA and NCA are available on R.

6. Conclusion

In the previous chapters, I argued for a configurational approach to maturity models research, developed a procedure model and method (STAMM) for this purpose, and subsequently demonstrated its application using three empirical datasets. In this final chapter I will provide my concluding remarks by discussing the contributions of this PhD thesis and my plan for further research.

6.1 Contributions

The primary contribution of this PhD thesis has been to the domain of maturity model research in Information Systems. The first theoretical contribution of this PhD project is the defining the components of a maturity model using the configurational perspective. By doing so, this thesis has contributed to the academic discussion on how maturation occurs through configurations of multiple complex conditions, also known as “equifinality”. The key contribution is STAMM, a set-theoretical procedure model and method, which employs FsQCA and NCA to empirically demonstrate multiple paths to maturity (or equifinality). In particular, this thesis conceptualizes and empirically uncovers stage boundaries of maturity models as necessary conditions using NCA (Dul 2016c), operationalizes maturation in terms of configurations using QCA (Ragin 2008), and demonstrates the existence of multiple paths to maturity beyond a linear single path.

On a practical side, this thesis provides researchers and practitioners with detailed procedures to systematically apply this approach. In particular, paper III is the first - ever attempt to employ set-theoretical approach to maturity model design and demonstrate its application. In this process, I have documented and discussed the challenges faced, while offering solutions to IS researchers interested in applying STAMM for maturity model design.

A second major contribution towards maturity models design is the introduction of empirically founded arguments to formulate maturity stages. As discussed in paper III, the process of arriving at the number of maturity stages was arbitrary in all previous inductively designed maturity models. Instead of this arbitrary selection of number of stages, STAMM proposed three strategies to formulate maturity stages and their boundaries. By employing the concept of degree of necessity (from NCA), STAMM ensures that the number of stages are analytically derived and not arbitrarily decided.

A third contribution of this thesis is to successfully complement NCA with QCA and provide future IS researchers with three demonstrative use cases. In particular, the PhD thesis highlights the importance of using both NCA and QCA to identify necessary conditions; in the process providing detailed guidelines on how to do so. This thesis is one of the first few studies wherein NCA and QCA are combined to uncover empirical insights. For example (paper VI), using a demonstrative case on ITSM maturity, this thesis provides guidelines and templates to harmoniously integrate knowledge gained from PLS-SEM, QCA and NCA⁴⁸. By doing so, this thesis adds to limited body of STA literature (Fiss 2007; Greckhamer et al. 2013; Liu et al. 2017) arguing to complement and supplement mainstream symmetric relationship based statistical methods like PLS-SEM with the asymmetric relationship perspectives using set theoretic approaches. As established in paper V1, the use of STAMM proved a valuable addition to PLS-SEM, as some important empirical findings would have remained hidden with only PLS-SEM analysis, thus providing a positive use case for IS researchers.

6.2 Managerial Implications

First, by employing STAMM managers can uncover multiple pathways to mature towards a desired end stage. Second, STAMM advocates for identifying single necessary conditions (known as boundary conditions) as without them, an organization will not progress towards maturity. These boundary conditions are actually obstacles and/or bottlenecks and must be addressed before managers focus their attention on other conditions. Both these strengths of STAMM has significant managerial implications.

For example, in the analysis of ITIL maturity using STAMM (i.e. paper V), I uncovered that an organization could take five pathways towards the highest level of ITIL maturity as compared to the prior research (e.g. Marrone and Kolbe 2011a) that modelled a single linear path. While the linearity assumptions in prior research led to conclusions that as more processes of ITIL are implemented, the perceived maturity of the ITIL implementation increases, STAMM enriched these prior conclusions that IT executives would implement Service Support (SS) processes first and then start implementing the Service Delivery (SD) later. STAMM also uncovered that IT executives would definitely not implement more than two of the five Service Delivery

⁴⁸ QCA and NCA employed to corroborate, relativize, contradict and explain statistical associations established using traditional statistical techniques like PLS-SEM (Paper VI). The result of paper VI is an extended version of STAMM for primarily IS behavioural science researchers in maturity model research who are interested in hypothesis testing. This extension gives researchers guidelines to combine STAMM with PLS-SEM or multivariate regression analysis.

(SD) before they progress to ITIL maturity level of 3 (Defined). These findings definitely has managerial implications, as managers implementing ITIL processes could focus on implementing Service Support (SS) processes before focusing on all processes simultaneously. Another example is the relationship between business-IT alignment (BITA) and ITIL maturity. While Marrone and Kolbe (2011a) showed levels of business-IT alignment increases significantly with ITIL maturity, STAMM adds to this finding by uncovering that BITA as an obstacle for highest level of ITIL maturity. Moreover, STAMM also uncovers that lower levels of ITIL maturity does not necessarily mean low BITA. From a managerial perspective, IT executives can realize high levels of business-IT alignment even before realizing higher levels of ITIL maturity and subsequent benefits from its implementation.

Managerial Implications of employing STAMM combined with PLS-SEM are also discussed in detail in paper VI. One such finding was the presence of both Conservative IT and Innovative IT strategy (ambidextrous) being simultaneously necessary⁴⁹ for realising very high service operations (SO) maturity, provided other conditions like system criticality and IT employee capability are in place. While prior research (Winkler et al. 2015) argued that innovative IT strategy is expected to be negatively associated with SO maturity, STAMM uncovered the possible need for managers to employ an ambidextrous IT strategy while progressing towards highest level of maturity.

6.3 Future Research Work

Based on my reflections during the practical implementation of STAMM on real datasets, several methodological and practical limitations were encountered as discussed in detail in Chapter 5.2. These limitations have resulted in my avenues for future research as discussed below.

First, all three the datasets used for demonstration comes from secondary sources. I as a researcher had little to no control over the formulation of the questions, strategy for data collection or the choice of conditions. For instance, the social media maturity dataset used (NBI), although practically relevant and used by practitioners, academic researchers would argue that the conditions and questions asked are rather simplistic. Moreover, this dataset did not have enough positive cases to derive configurations for the very high maturity stage. That said, I used dataset 1 to conceptualise maturity using set-theoretic methodology and the purpose of the dataset is to demonstrate the method

⁴⁹ Finding from paper VI: Yes, Innovative IT strategy is negatively associated with SO maturity, but only to a certain level. Innovator IT strategy could be necessary for very high service operations maturity.

using a real-world dataset that was available to me at that time. In order to address this limitation, I approached multiple researchers including those that have been published before in IS or related journals such as the E-Government Maturity Model (Andersen and Henriksen 2006), BI Maturity (Raber et al. 2012), Intranet Maturity Model (Damsgaard and Scheepers 1999), ITIL (Marrone and Kolbe 2011a), ITSM (Wulf et al. 2015) and managed to acquire the last two (i.e. dataset 2 and 3). However, both these datasets too had their own set of challenges as they were developed to suit an analysis using correlational techniques. Dataset 3 in particular was tailor made primarily for techniques like factor analysis and multivariate regression analysis. Therefore, as part of future research, I would venture into a project wherein I fully control the development of a maturity model and the data collection. My goal would be to employ purposeful sampling and then employ STAMM, in the process enrich the STAMM procedural model further.

Second, the discussion regarding the use of logistic transformation for calibration is an ongoing fierce debate in the QCA community and this PhD thesis is no different. As discussed in all the three papers (III, V and VI), I opted for logistic function transformation based on recommendations by prior published papers and now consider my rationale for this choice as very practical⁵⁰. I will use dataset 3 (ITSM maturity) to further elaborate my point. Figure 13(a & b) below compares the consequences of using logistic or linear calibration. First, figure 13a illustrates how logistic calibration moves the cases from the middle of the scatter plot towards its corners. Since NCA captures necessary conditions using the size of the empty area on the upper-left corner, Dul (2016a) recommends either using non-calibrated data or using the linear function. However, this choice has direct consequences on the benchmarks (frequency threshold and inclusion criterion) as illustrated in figure 13b. Figure 13b clearly indicates the relationship between choice of calibration membership function and benchmarks. If one uses the linear function with a recommended inclusion criterion of 0.75 or 0.8 all the cases will explain the outcome, thus leaving the set of below average maturity almost empty. Therefore as a practical solution, prior papers have recommended to use the logistic function along with an inclusion criterion of 0.75 or 0.8. However, since both the choices were made on a practical need rather than strong theoretical arguments, I consider these choices weak. While existing research on this is limited, I will explore the sensitivity analysis (Thiem 2014) and experiment with different calibration choices as part of my future work.

⁵⁰ Ragin (2008) also acknowledges that choice of logistic (log of odds) calibration is an arbitrary choice, solely based on empirical relevance rather than theoretical arguments.

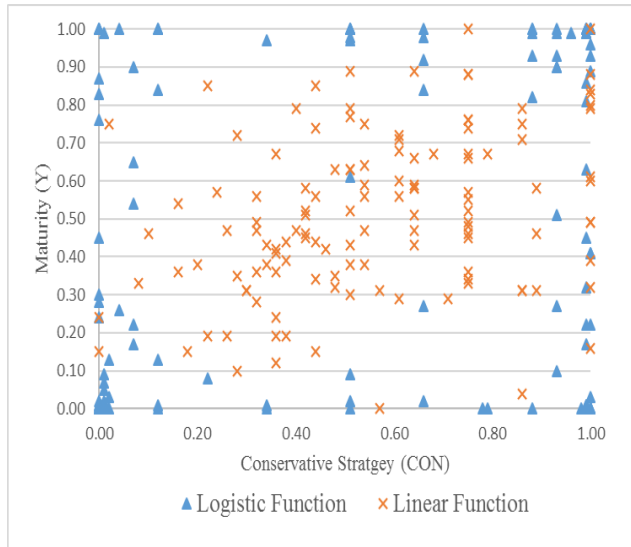


Figure 13a: Logistic Vs. Linear Calibrations

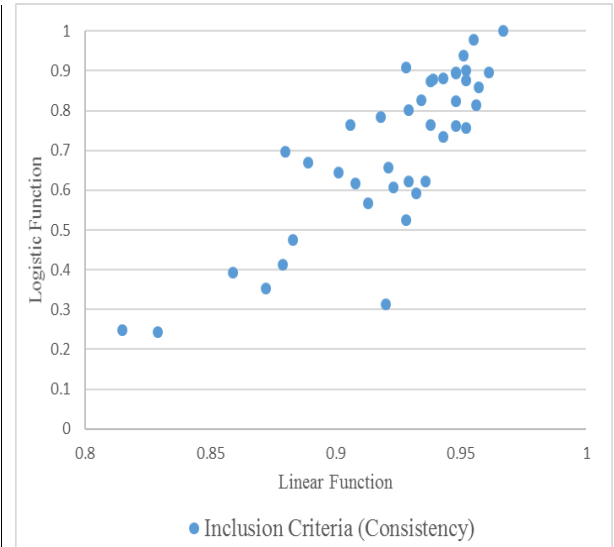


Figure 13b: Impact on Boolean minimization.

On similar lines of argumentation, the impact of different ceiling lines for NCA and its impact on the final results would also be part of my future work.

Finally, while I explore and demonstrate that multi-method approach by combining PLS-SEM, NCA and QCA provide valuable insights, I have not qualitatively discussed the final maturity configurations nor the cases that contribute/contradict these maturity configuration. Moreover, the findings are preliminary and would need further validation. This is mainly because the data comes from surveys and lack of deep knowledge about the cases made qualitative assessment very difficult. My future work would be continue collaboration with Wulf et al. (2015), acquire more data and have theoretical discussions on the different configurations. Moreover, a thorough investigation into the deviant cases⁵¹ would also be part of my future work.

⁵¹ An attempt to add to Winkler et al (2015)'s benchmarking tool (<http://itil.selfsurvey.org/>) is ongoing and visualization of deviant cases using a table dashboard can be found here: <https://public.tableau.com/profile/lesterlasrado#!/vizhome/TillWinkler/Story1>

7. Appendix

7.1 Set Theoretic Approaches in IS Research.

Table 10: QCA in IS research.

Authors	Purpose & Research Design	Methodological observations	Authors' conclusions about QCA	How were the sets calibrated?	Outlet
(Liu et al. 2017)	<p>Primary task of this research is full interpretation of the given IS phenomenon using a multimethod approach (QCA & SEM).</p> <p>Large N survey (N=409) on rural residents' intention to use mobile government services in China.</p>	<p>a. FsQCA; Fiss</p> <p>b. $c=6$; $\min\text{incl}=0.93$; $n=3$; Direct Linear Calibration</p> <p>c. No Necessary Condition Analysis</p> <p>d. $\text{Con}=0.919$; $\text{Cov}=0.655$</p> <p>e. Negation analyzed</p> <p>f. No Robustness Tests</p> <p>g. Measurement validity, reliability through SEM</p> <p>h. R for calibration & Fs/QCA 2.0</p>	<p>Main benefit of FsQCA lies in supplementing econometric methods like PLS-SEM.</p> <p>FsQCA was originally developed to measure one-item factors, hence they propose integrating the advantages of a measurement model test using SEM.</p>	<p>A membership value of 1 was assigned to respondents who answered 5, 0 was assigned to an answer of 1, 0.4 was associated with 3, and the membership values for other answers were specified between 0.70 for an answer of 4 and 0.20 for 2.</p>	ISJ

		for analysis			
(Iannacci and Cornford 2017)	<p>Research strategy integrates QCA with process tracing to unravel “the causal and temporal influences in determining IS success”</p> <p>Small N in-depth case study adopted (N=7) for monitoring disbursement and use of resources within the European social fund.</p>	<p>a. FsQCA; Fiss</p> <p>b. c=5; macro conditions=2 ; min incl=0.85; n=1; Indirect Calibration only based on case knowledge.</p> <p>c. No Necessary Condition Analysis</p> <p>d. Con=1; Cov=1</p> <p>e. Negation analyzed</p> <p>f. No Robustness Tests</p> <p>g. Logical remainder discussed in detail</p> <p>h. Fs/QCA 2.5 for analysis</p>	<p>The integration between fsQCA and process tracing allowed structured iterations between theory and cases, thus linking theoretical and empirical strands more closely together.</p>	<p>Each of 7 countries/regions was assigned to that combination of aggregated conditions. These were arrived at after a detailed examination of qualitative case data at hand.</p>	ISJ
(Park and El Sawy 2013)	<p>Firm-level field survey (N=109) of managers in Korean companies</p>	<p>a. FsQCA; Fiss</p> <p>b. c=6; min incl=0.9; n=3; Direct Calibration,</p>	<p>FsQCA can better explain the holistic nature of digital eco-</p>	<p>Conditions measured using a 7-point Likert scale: with 1= lowest, 4=ambiguous</p>	Book

	describe how IT systems, organizational dynamic capability and environmental turbulence simultaneously combine to produce competitive firm performance.	<p>but no information about type of function (linear, logistic, etc.)</p> <p>c. Necessary Conditions Analyzed</p> <p>d. Con=0.87; Cov=0.74</p> <p>e. Negation not analyzed</p> <p>f. No Robustness Tests</p> <p>g. Measurement validity, reliability through SEM</p> <p>h. Fs/QCA 2.5 for analysis</p>	dynamics.	(crossover) and 7=highest level. This study defines the interval scale 2 as the anchor for full non membership, 4 as the crossover point, and 6 for the full membership.	
(Leischnig et al. 2016)	Explore configurations of digital business strategy i.e. factors related to firms' market approaches, and environmental factors to	<p>a. FsQCA; Fiss</p> <p>b. c=5; min incl=0.8; n=3; Direct Logistic Calibration</p> <p>c. PRI threshold at 0.8, also assessed proportional</p>	<p>QCA shows alternative pathways or "causal recipes" to high market performance.</p> <p>QCA can provide insights that</p>	<p>Conditions measured using a 7-point Likert scale: with 1= lowest, 4=ambiguous (crossover) and 7=highest level. This study defines the interval scale 2 as the anchor for</p>	ICIS 2016

	<p>explain superior market performance.</p> <p>Moderate N survey (N=121) of managers working for companies with 100 to 250 employees.</p>	<p>reduction in PRI.</p> <p>d. Necessary Conditions Analyzed</p> <p>e. Con=0.91; Cov=0.63</p> <p>f. Negation not analyzed</p> <p>g. No Robustness Tests</p> <p>h. Measurement validity, reliability through SEM</p> <p>i. Fs/QCA 2.5 for analysis</p>	<p>may complement those obtained by linear-algebraic methods.</p>	<p>full non membership, 4 as the crossover point, and 7 for the full membership.</p>	
(Levallet and Chan 2015)	<p>The study consisted of a 2014 survey of 100 companies in “dynamic” environments, especially from a technology perspective. The sampled organizations are mostly service organizations</p>	<p>a. CsQCA; Decision Flowchart</p> <p>b. c=7; macro conditions=3 ; min incl=0.75; n=3; Direct Calibration</p> <p>c. Necessary Conditions not analyzed</p> <p>d. Con=0.91; Cov=0.63</p>	<p>Set-theoretic methods differentiate core elements with a strong relationship to outcomes from those with weaker or no links.</p> <p>Different paths and conditions, i.e., there can</p>	<p>Crisp sets i.e., 0 for absence and 1 for the presence of a condition. The cutoff value determined by the factor score distribution, specifically the mean with normal distribution and the median with non-normal</p>	ICIS 2015

	located in Canada.	<p>e. Negation not analyzed</p> <p>f. No Robustness Tests</p> <p>g. Measurement validity, reliability through SEM</p> <p>h. Fs/QCA 2.5 for analysis</p>	be equifinality.	ones.	
(Fedorowicz et al. 2015)	Studies characteristics of governance that distinguish low and high performing inter-organizational coordination hubs using data from 61 public safety networks (PSN).	<p>a. FsQCA; Author's own tabular format</p> <p>b. $c=6$; min incl, and n not discussed in the paper; Both Direct Linear Calibration</p> <p>c. Necessary Conditions not analyzed</p> <p>d. $Con=0.91$; $Cov=0.63$</p> <p>e. Negation not analyzed</p> <p>f. No Robustness Tests</p>	QCA analysis makes clear there exist multiple paths or configurations that can achieve high levels of performance.	<p>Explorative survey, hence each condition coded differently. E.g. Governance performance score is coded 1 if answers to the survey are Positive i.e. "improve a lot" or "strongly agree". Negative responses like "worsened" and "disagree" are coded 0, and rest in between i.e. 0.33, 0.51, and 0.67.</p>	ICIS 2015

		g. Fs/QCA 2.0 for analysis			
(Bardaki et al. 2013)	CsQCA) as a secondary method to pinpoint specific design solutions that achieve high IQ.	Author combines CsQCA with cluster analysis to determine the range of IQ values corresponds to high, medium and low IQ. a. Steps not discussed and all details not provided b. Con=0.929; Cov=0.727	It is the first time CS/QCA is applied to support the design process of information systems and, specifically, object tracking systems.	Unlike a survey (direct calibration), the process in this paper is very contextual and discussed in detail in the paper.	ICIS 2013

7.2 Calibrated Data

Table 11: Data used for QCA sufficiency analysis with midpoint as 0.5.

Case	FUE	MUS	ITP	INV	SK	M	EEC	PSC	NSC	BVH
CA2	0.55	0.91	0.91	0.99	0.99	0.01	0.97	0	0.99	0.99
CA6	0.92	0.99	0.01	0.99	0.91	0.01	1	0.82	0.99	1
CA7	0.09	0.01	0.91	0.99	0.09	0.01	0.99	0.82	0.99	0.01
CA10	0.01	0.01	0.96	0.99	0.01	0.01	0.99	0.99	0.99	0.79
CA16	0.55	0.91	0.82	0.99	0.09	0.01	1	0.01	0.01	0.43
CA20	0.55	0.01	0.91	0.01	0.09	0.01	0.97	0	0.01	0.43
CA21	0.55	0.99	0.01	0.99	0.99	0.55	0.99	0.82	0.99	0.15
CA37	0.01	0.09	0.01	0.01	0.91	0.01	0.24	0.96	0	0.04
CA41	0.55	0.91	0.91	0.99	0.91	0.55	0.91	0.96	0.91	0.99
CA46	0.55	0.99	0.99	0.99	0.91	0.99	0.91	0.96	0.91	1
CA54	0.01	0.99	0.96	0.99	0.09	0.01	0.24	0.82	0.91	0.04
CA57	0.01	0.91	0.01	0.01	0.99	0.01	0.76	0.01	0.91	0.04
CA62	0.55	0.91	0.96	0.99	0.91	0.55	1	0.96	0.99	0.15
CA78	0.55	0.91	0.01	0.99	0.99	0.55	0.76	0.96	0.99	0.43
CA80	0.55	0.91	0.01	0.99	0.91	0.01	0.03	0	0.91	0
CA84	0.55	0.91	0.91	0.99	0.91	0.01	0.09	0.96	0.91	0.79

1. The full data (calibrated) for high maturity (dataset 1) can be found:
<https://www.dropbox.com/s/n57jc44a8jpt8ee/QCAMEMG2BHC.csv?dl=0>
2. The full data (calibrated) for very high maturity (dataset 1) can be found:
<https://www.dropbox.com/s/rbqzdcjaa1va3uu/QCAMEMG2BVHC.csv?dl=0>
3. The full data (calibrated) for dataset 2 (ITIL Maturity) can be found:
<https://www.dropbox.com/s/ahuulqckczthaua/Final%20analysis%20data.xlsx?dl=0>
4. The full data (calibrated) for dataset 3 can be found:
https://www.dropbox.com/s/k7rrf21is9jblh5/qcavalues_12th%20July2017.csv?dl=0

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Paper I: Maturity Models Development in IS Research: A Literature Review

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MATURITY MODELS DEVELOPMENT IN IS RESEARCH: A LITERATURE REVIEW

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Abstract

Maturity models are widespread in IS research and in particular, IT practitioner communities. However, theoretically sound, methodologically rigorous and empirically validated maturity models are quite rare. This literature review paper focuses on the challenges faced during the development of maturity models. Specifically, it explores maturity models literature in IS and standard guidelines, if any to develop maturity models, challenges identified and solutions proposed. Our systematic literature review of IS publications revealed over hundred and fifty articles on maturity models. Extant literature reveals that researchers have primarily focused on developing new maturity models pertaining to domain-specific problems and/or new enterprise technologies. We find rampant re-use of the design structure of widely adopted models such as Nolan's Stage of Growth Model, Crosby's Grid, and Capability Maturity Model (CMM). Only recently have there been some research efforts to standardize maturity model development. We also identify three dominant views of maturity models and provide guidelines for various approaches of constructing maturity models with a standard vocabulary. We finally propose using process theories and configurational approaches to address the main theoretical criticisms with regard to maturity models and conclude with some recommendations for maturity model developers.

Keywords: Maturity models, maturity, development, design, process theories, organizational change.

I.1 Introduction

Stage models, maturity models, and benchmarking of IT performance has always been a controversial field and Scandinavian researchers have not been keen on taking this branch of research onboard in the IS field. Not the least, in a Scandinavian context where involvement in system development and field work have been highly influential. Whereas it is true that earlier generations of maturity models were often populated by experts' assessments, laboratory experiments, student assessments, or relatively in-transparent data estimation processes, their maturity continued to be refined and adopted. In the past 15 years, we found only two papers i.e. one on developing a maturity model and other on the use of software capability maturity models within SJIS and published IRIS proceedings. We make the daring proposition that closing the Scandinavian eyes to maturity model research would be ignoring a vital part of IS practice. Therefore, in the paper we seek to unfold what the IS literature has generated in terms of knowledge for the development of maturity models.

Maturity models in IS are understood as tools that facilitate internal and/or external benchmarking while also showcasing future improvement and providing guidelines through the evolutionary process of organizational development and growth [26]. The term “maturity” is defined as “the state of being complete, perfect or ready” [26]. In Information Systems (IS) literature, the concept has been employed to develop an understanding of evolution of Information systems [18] and the most common type is the stage growth model. Extant literature in IS on maturity models ranges from Nolan's stage hypothesis of IT in organizations, its assessment and criticisms [17, 22] to the application of its seminal model for other enterprise systems such as intranet [9]; IS/ICT capability [37] and many more. Further, the capability maturity model (CMM) [31] has been widely accepted as standard and adopted over a wide range of problem areas [33]. From an academic perspective, the number of publications on maturity models has risen ten times on a yearly basis over the last decade; from 20 in 1994 to 115 in 2008 [4]. The evolution of emerging technologies has seen a surge of maturity models in academic publications e.g. web and social media [18, 24], analytics [10, 7] and especially consultancy models i.e. Deloitte [15], Accenture [14] to name a few. Apart from academics and government consortiums, consultancies (Gartner, Forrester, etc.) have played an important role in making “maturity models” popular among practitioners.

The certification culture that started with the advent of Capability Maturity Model e.g. Paulk et. al [31], CMMI [6] has motivated consultancies to develop maturity models,

thus increasing its popularity among practitioners. Maturity models are also increasingly adopting the design science research paradigm and citing procedure model frameworks proposed by Becker et.al [3], De Bruin et.al [11] and Solli- Sæther et.al [39] as methodological steps while designing the models. However, with regard to validation of maturity models, developers face huge challenges in defining the parameters of comparison due to the lack of a standard vocabulary to address the diversity among models.

In this paper we address these challenges by (a) reviewing the extant literature on maturity models in IS, (b) identifying standard vocabulary used in literature, and finally (c) generating recommendations to resolve these challenges. In line with this objective, the paper probes the following research questions: (a) what are the types of maturity models - is there a generic structure for maturity models in IS? (b) What are the prescribed vocabulary and guidelines to assist researchers while developing maturity models? (c) What are some theoretical considerations that could be taken into account while developing maturity models; e.g. defining path to maturation and levels of maturity?

1.1.1 Literature Review: Method and Data Collection

To answer the research questions, we conducted a systematic literature review of the academic research on maturity models in the IS domain. In order to progress with the literature review, a keyword search was done on electronic databases (i.e. ACM digital library, AIS electronic library, IEEE explore, Springer link and Business source complete). The selection criteria were that the research article must include at least one of the following conditions

- 1) Detailed documentation of entire development process; Articles must construct a new maturity model.
- 2) Application of empirical methods in constructing or operationalizing maturity models.
- 3) Discussion on constructing a maturity model, while proposing principles and meta-guidelines aiding the design process.
- 4) Detailed literature review on maturity models.

The search process included use of the term ‘maturity model’, ‘maturity model design’, ‘stage of growth’, ‘capability maturity’, ‘maturity grid’ as well as combination of

possible alternative terms, e.g. ‘maturity’ and ‘design’, ‘stage of growth’ and ‘design’ in the “abstracts” search field. Overall the search was restricted to the last 15 years (1999 to 2014) and yielded a total of over 600 academic articles, hence indicating the popularity of the concept of maturity models. Given the vast number of publications we decided to apply filters as recommended by Webster and Watson [44] to first start with the leading journals as it most likely to have articles with significant and relevant contributions. Figure 1 provides the summary of the entire process with the number of selected publications.

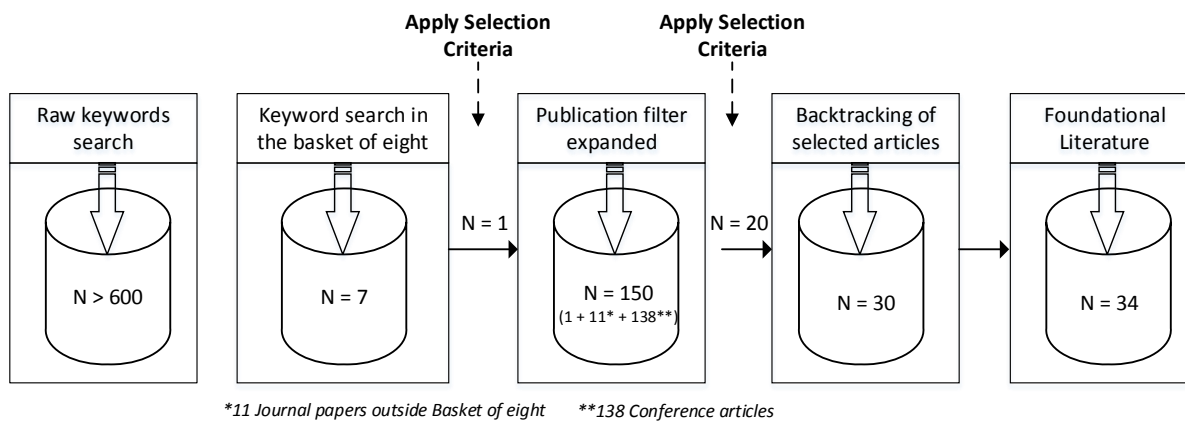


Figure 1. Literature review process and resulting number of article.

As our research was restricted to the IS domain, we first checked the “Basket of Eight” journals as identified by the Association for Information Systems (AIS). This yielded 7 results in the Basket of Eight, however only one paper i.e. Damsgaard and Scheepers [9], satisfied our criteria and was included in the review. The search was then expanded to other IS journals on AIS electronic library, resulting in 11 more articles out of which we selected four i.e. Van Steenbergen et.al [43], Becker et.al [3], Pöppelbuß et.al [33] and Wendler [46] to be included in the review. Given the low count of journal articles, we expanded the search to IS conference proceedings, resulting in 138 articles which were all read and analyzed in detail, out of which 15 were selected for making recommendations. The papers compiled from the above two searches were subjected to rigorous process of backtracking and an additional 9 articles were found. These articles were added to the selected literature list that was thoroughly reviewed again including Davenport and Harris [10] that was published in form of a book, given the popularity of this model. In addition to above, foundational articles on maturity models by Nolan and Gibson [30], Crosby [8], King and Kræmer [22], Paulk et.al [31] was also reviewed. Finally, as indicated in figure 1, a total of 34 articles constituted the literature corpus to make the final recommendations.

I.2 Maturity Models literature review– Results and Analysis

An overarching finding from our analysis is that there are three world views of maturity models depending on the purpose of use and motivation behind its development. The first world view portrays them as normative theories e.g. [9, 30, 37], that are predominantly grounded as process theories which as explained by Van De Van and Poole [42] feature a narrative story, with events happening around a focal actor or main entity in a chronology over a sequence of time becoming mature towards the better [4]. The second view portrays them as “best practice guide” or “certification mechanism”, especially post the success of Capability maturity model (CMM). The forward of Capability maturity model document [31] stated “throughout the development of the model(CMM) and the questionnaire, the SEI (developers of the model) has paid attention to advice from practitioners....is based on actual practices, reflects the best of the state of the practice” e.g. [6, 12, 20]. The third and final world view portrays maturity model as a practical benchmarking tool, wherein organizations are classified and compared against each other using a scale of low to high maturity; e.g. [25, 36].

I.2.1 Generic structure of maturity models in IS literature

From the papers analyzed, we found that maturity models are often classified using terms like stage fixed level models, stage continuous level models or focus area models [41]. This classification is multifaceted and dependent on number of factors like scope of the model, abstraction level and other characteristics. The purpose of maturity models is to outline the path to maturation, including defining the stages and relationship between them [38]. The underlying assumption of these models is that a higher degree or score of maturity also means increased positive change in several dimensions with the model capturing this maturation process while providing an artificial construct to measure progression.

A compilation of the characteristics of maturity models and their corresponding definitions can be found in a tabular format in Appendix 1(table 2). We identified five important components to describe a maturity model i.e. (i) Maturity Levels also known as stages, levels, maturity score, etc. used to describe the overall summary or maturity of the entity and the level of abstraction at the highest level, (ii) Dimensions (table 2; row 14), (iii) Sub-categories (row 15), (iv) Path to Maturity (row 9 to 12), and finally, (v) Assessment Questions which are usually directly linked to the sub-categories with

the maturity score or level visualised usually as a graphical representation. Combining all the above, we present the generic structure of a maturity model in figure 2 that is divided into two parts.

The first part depicts the generic design structure of maturity models comprising of the different stages each with different dimensions and sub-categories. The second part depicts the hierarchical relationships between the typical components of the maturity model. The analysis of literature also highlighted four main challenges while developing an instrument to measure maturity i.e. (i) how to measure distance between maturity levels (ii) what is the scale of measurement (iii) how to address the additivity challenge and calculate overall maturity and (iv) where do the dimensions come from. Other associated challenges range from defining the maturity levels to operationalizing relationship between different dimensions and maturity levels. Recent literature in IS has tried to answered the above questions as discussed in the next section.

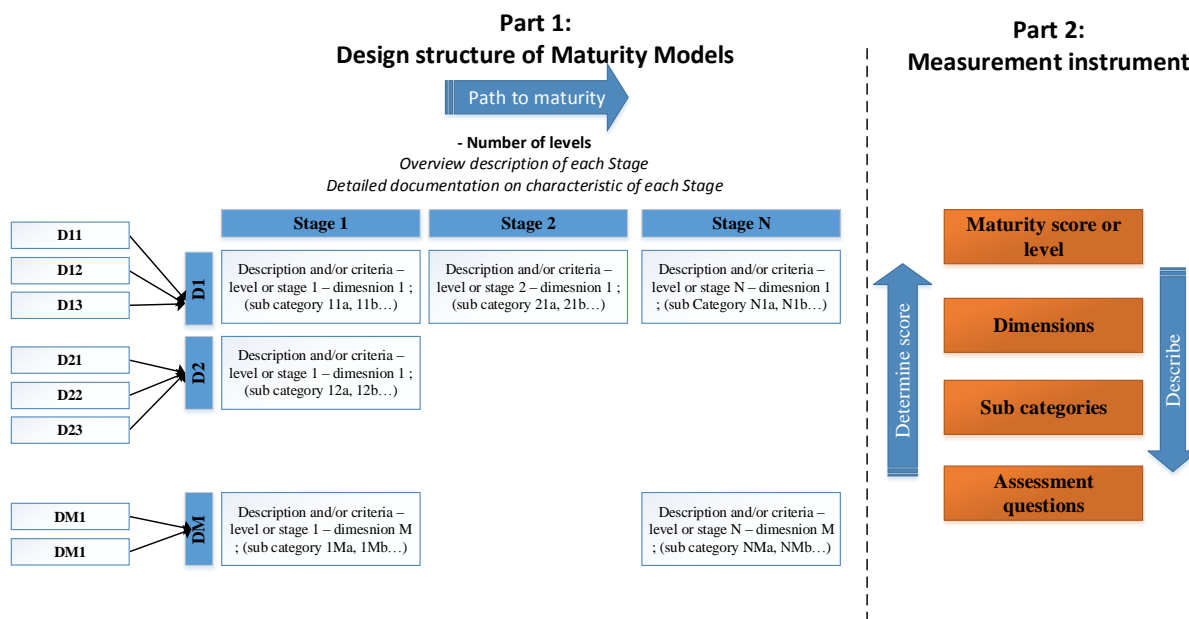


Figure 2. Schematic Representation of Generic Structure of the Maturity Model.

1.2.2 Maturity Models Development: Guidelines in IS Literature

Recent literature in IS has predominantly focused on developing new maturity models, e.g. [2, 12, 18]. However, there has been a significant effort recently by a few researchers to standardize maturity model development and research through prescriptive guidelines, standardized vocabulary and validated procedure. Focus area model [43] follows the design science paradigm, while De Bruin et.al [12] proposes a 6

phase model of development along with the concept of maturity model layers and a schema for defining characteristics (Table 2). Becker et.al [3] proposes a detailed 8 step procedure model based on design science guidelines. Furthermore, Solli-Sæther et.al [39] proposes a modelling process for stage models while clearly theorizing core topics of stages of growth, considering theoretical criticisms as shown in table 1.

All the three approaches (Table 1) advocate a step by step iterative sequential approach for developing a maturity model. Further, all three approaches emphasize operationalization and validation to ensure practical relevance. In addition to the three approaches, Mettler et.al [26] identifies two approaches of constructing a model i.e. *top-down* (first defining maturity stages and then creating dimensions and adjusting measures to fit the definitions) or *bottom-up* (requirements and measures are determined first with definitions of stages later). However, this raises a question for maturity model developers: what approach to use and when? A clear answer is given by De Bruin et.al [11] that *top-down* approach works for a relatively new domain as there is little evidence of what is maturity among the community. In a well-established domain, the focus would be on how maturity is measured rather than what represents maturity, thus requiring the *bottom-up* approach. That said, Solli-Sæther et.al [39] proposes a sequential step-by-step recipe irrespective of the newness of the domain. Therefore, it could be concluded that there are no hard and fast rules to decide the approach, but it is important to use existing literature and validate the dimensions and constructs of a maturity models empirically.

I.2.3 Methods for Developing Maturity Model Constructs and Scoring Algorithms

This section explores the actual maturity model development processes documented in IS literature. An article Wendler [46] studied 237 articles and categorized maturity models as conceptual and design-oriented, while indicating a gap in evaluating and validating maturity models. Moreover, similar to many other authors in the past, Wendler [46] also questioned the “rigor” of the maturity models stating that only 7 out of 105 maturity models reviewed by him have used empirical i.e. qualitative or quantitative methods for development of validation. Our study in IS also provided similar results and we classified models depending on the construction of dimensions and levels in figure 3, wherein process of deriving constructs is classified as

- *Conceptual*: Maturity models that use theoretical approach to deriving dimensions; e.g. socio technical theory, RBV, etc. A strong theoretical foundation is necessary and not just mention of previous maturity models to be classified in this category.
- *Qualitative*: Models that use predominantly qualitative empirical approach to derive dimensions and levels are classified into this category.
- *Quantitative*: Models that use predominantly quantitative empirical approach to derive dimensions and levels are classified into this category.
- *Derivative*: In this category models that predominantly use prior published maturity model literature and fit relevant domain problems into the structure without strong theoretical or empirical foundations are classified. This category also accommodates models are developed keeping solely a practitioner perspective and are not targeted towards academic audience.

In line with Wendler [46], most of models analyzed by us in IS were predominantly *conceptual* in nature, when it comes to deriving dimensions and maturity levels as shown in table 3 (Appendix 2). Majority of lately published models use procedure models proposed by Becker et.al [3] or De bruin et.al [11]; however deriving dimensions either conceptually or derivatively. Empirical validations of the models are scarce and authors usually continue by operationalizing the instrument (i.e. survey) to classify organizations and propose some conclusions.

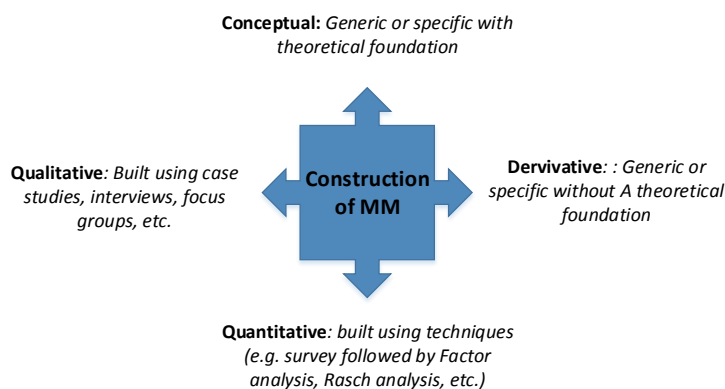


Figure 3. Methods adopted in building maturity model constructs.

Qualitative methods are used more frequently than quantitative techniques while developing maturity model constructs. A literature study is usually followed up by a conceptual maturity model, which is then verified and tested through focus groups,

Delphi methods and/or interviews before operationalizing the measuring instrument (the process is iterative); e.g. [9, 12].

Quantitative methods are less frequently used for constructing maturity models [23], with a few examples of use of the *Rasch algorithm-based approach* [13], e.g. [5, 34, 35] all use socio technical theory and Rasch algorithm proposed earlier to empirically design the BI maturity levels and subsequently operationalizes this model [36] using the twofold application of the *Euclidean metric* i.e. “the squared statistical distance is used to measure BI maturity” with items measured on a five-point Likert scale and thus the distance between the maturity levels. The same approach was used by Nils Joachim and Weitzel [28] to measure SOA maturity while a paper by Wulf et.al [47] conceptualizes IT service management (ITSM) by adopting dimensions from four existing maturity models and performing exploratory factor analysis, thus validating the dimensions and developing multi-attributive scale to assess maturity on an ITSM process level.

Overall, this section discussed in detail the concept of maturity models, process of design and developing a maturity model, introduced standard vocabulary and guidelines and finally highlighted various approaches to deriving the constructs of a maturity model while highlighting gaps. One conclusion, that can be drawn is that many IS researchers lately have used and/or cited design oriented approach while developing a maturity model. However most of the literature has been conceptual and and empirical validation could definitely increase the rigor of maturity models.

I.2.4 Three Common Criticisms of Maturity Models

Maturity models have been swamped with criticisms with Nolan’s evolutionary model facing the bulk of it with King and Kræmer [22] famously questioning the lack of empirical validity, factually mistaken structural assumptions and for being too simplistic to be useful. Maturity models in IS since the publication of Nolan and Gibson [30] have mostly taken a stage based lifecycle or evolutionary approach while describing entities path to maturity. Core assumption of stage models is that predictable patterns exist and unfold as discrete time periods best thought of as stages. The main criticism by King and Kræmer [22] was the evolutionist approach that made Nolan’s model closer to have a lifecycle approach without having enough historical evidence to make such predictions. Overall there are three major criticisms with regards to maturity models -

- Lack of theoretical foundations with models adopting for e.g. CMM as their structure and not conceptually grounding the structure (Maturity levels, dimensions, etc.) from literature [32, 37],
- Lack of strong empirical validation in selection of dimensions or variables [23],
- Lack of operationalising maturity measurement [4], with Solli-Sæther et.al [39] stating that the research work *related to stages of growth has to a large extent been conceptual while the debate over existence of stages itself has suffered from a lack of empirical evidence.*

In addition to the above three, we believe that the concept of one linear way towards maturation is not right and not acknowledging the notion of equifinality is also a major criticism that needs to be addressed. Very few maturity models have acknowledged and addressed these challenges - e.g. Damsgaard and Scheepers [9] addresses the criticism on evolutionist approach, while Raber et.al [34] proposed an inductive way of structuring dimensions and levels, otherwise most of the literature has been conceptual and poorly grounded in theory (table 3). This highlights the need for further research on topics concerned with measurement of maturity, accuracy of the evolutionary path indicated and economic impact of maturity levels [39]. In the following section we propose a solution based on process theories in organisations that could address some of these criticisms.

I.3 Conclusion: Towards Theoretically Grounded Maturity Models

I.3.1 A Process Theory Approach

It is very evident that the main criticism of maturity models with respect to the underdeveloped or absent theoretical explanations for the path to maturity and evolution in stages is not satisfactorily incorporated in the guidelines discussed earlier. To address this criticism, we propose employing process theories of organisations to conceptualize the path to maturity and the evolutionary stages. Van De Van and Poole [42] classify process theories into four distinct classes of underlying “ideal-types”, which are life cycle, evolution, dialectic, and teleology theories and the same could be used while conceptualizing maturity [32]. Van De Van and Poole [42] showcased 14 different logically possible theories of change (pp.528) combining the four distinct classes of underlying “ideal-types”. For instance, the famous organizational crisis stage model by Greiner is explained as a combination of lifecycle and dialectal types. Table

4 (Appendix 3) presents our application of process theories to classify the five selected maturity models in IS. The classification of the five maturity models in Table 4 (Appendix 3) is based on our understanding of Van De Van and Poole [42], wherein we interpreted most of the models above as predominantly lifecycle type with glimpses of evolutionary, teleological and dialectical types. We strongly believe that the line of thought advocated by Plattfaut et.al [32] about using process theories while conceptualizing maturity is a way of addressing the criticisms pertaining to lack of theoretical considerations.

I.3.2 A Configuration Theory Approach

There is a strong belief among researchers that better processes as described in a maturity model also means better or higher outcomes or results or performance. Even though this assumption sounds logical, according to Mullaly [27] there has been very minimal or almost negligible evidence in literature that improvements along the path of maturation also correspond to derived incremental value. Similar doubts on this fundamental assumption of many maturity models have been echoed directly by King and Kræmer [22], Pöppelbuß et.al [33] and indirectly by Cleven [5] too. Secondly, more often than not, “maturity” score or stage or level is an artificial or speculative measure used solely for benchmarking, which on its own means nothing when used in this comparative sense [1]. Finally, most of studies on maturity models from Nolan and Gibson [30], Crosby [8] to the recent ones by Winkler et.al [48] have advocated the linear path to maturity, while ignoring the notion of “equifinality” while defining maturity, which in the words of El Sawy [19] means an entity or system can reach the same outcome from different initial conditions and through many different path. Therefore, based on these three reasons, we call upon maturity model developers to apply configurational set theoretic approach advocated by El Sawy [19] and Fiss [20] to conceptualize maturity, as it assumes complex causality and nonlinear relationships, thus addressing many of the existing criticisms in literature.

I.3.3 Conclusions and Future work

In this paper we explored the established area of maturity model research and found that recent literature on maturity models in IS has focused on developing new maturity models and standardizing maturity model development processes. Our study yielded the following seven insights:

1. Majority of the IS maturity models can be described using a generic structure
2. There are three paradigms of maturity models in IS: normative theories, best practice guidelines and benchmarking tools
3. The path to maturation (i.e. something better, advanced, higher) is always linear, forward moving (rarely regressing), in which the entity improves considerably in terms of desired results i.e. capabilities, value creation, performance, etc. while traversing along this path. The notion of equifinality has not been acknowledged so far.
4. IS researchers lately have used design science approach while developing maturity models.
5. Most of the maturity models are predominantly conceptual in nature; very seldom did we find maturity models that use strong theoretical or causal approach or hypothesis testing approach.
6. There is a need for emphasis on empirically derived as well as validated dimensions and maturity levels.
7. There is a large scope for future research in applying empirical methods for constructing maturity models and measuring maturity itself.

Moreover, over the course of literature review, we also identified that researchers and practitioners alike find it very hard to locate a suitable and ready to use maturity model that has been validated amongst vast availability of literature. One of the reasons is the lack of theoretical considerations during model development and the lack of standard vocabulary for model description. Against this background and analysis, we propose the following recommendations to be adopted by maturity model developers:

1. Use any one of the three approaches for developing the maturity model (see Table 1). Even though the steps highlighted may not necessarily be in a sequential order, it is important to document the approach as this would help achieve standardization.
2. Use well-formulated process theories, configurational set theoretic approaches or both while conceptualizing and presenting path to maturity, in addition to making precise definitions of maturity, thus addressing the theoretical challenges and making theoretical interpretation possible.
3. Employ empirical methods in developing the constructs of the model and put efforts into validating existing as well as new maturity models, before dissemination.

4. Use standard vocabulary and guidelines (see Table 2) during the development and especially dissemination (publication) phase of the maturity models.

Over the course of this study, we have identified research gaps and plan to address them in our proposed future work. Firstly, we plan to address notion of equifinality while designing the constructs and path to maturity using fuzzy set approach, as adopted by El Sawy [19] and Fiss [20] while explaining organizational configurations. Secondly, we would also explore the phases prior to the decision of creating a maturity model through interviews with maturity model developers from all the three worlds i.e. practice, consultancy and academia, while also developing the criteria on which a maturity model can be deemed as successful or not. Finally, we would develop, validate and operationalize a social business maturity model using all the recommendations proposed in this paper.

The literature review in this paper has open the gates for further exploration and we encourage the Scandinavian community to join the efforts to qualify and further the research based knowledge and engagement in practitioner oriented development and use of maturity models. The technology momentum from social media and new data analysis techniques holds the potential to turn the concept of involvement in system development up-side-down and suggest new routes for Scandinavian researchers to follow.

I.Appendix.1 Three Meta models for Maturity models development process

Table 1: Three Meta models for Maturity models development process

6 Phases of Developing MM [11]	8 Steps to Developing MM [3]	5 Steps for Developing Stage of Growth MM [39]
<p>1. Scope – Set the outer boundaries for model.</p> <p>2. Design- Determine architecture of the model.</p> <p>3. Populate - Identify dimensions and sub-categories, describing detailed description in form of statements.</p> <p>4. Test – Relevance, rigor, validity, reliability in terms of both construct and content.</p> <p>5. Deploy – Deploy in phases, first among collaborators, then target audience and finally to entire population.</p>	<p>1. Problem definition – Determine scope, domain, target group.</p> <p>2. Study existing Models – Compare the problem with existing maturity model, review if there is need to develop new model. Document the study.</p> <p>3. Design Strategy – Determine design structure. Justify and document.</p> <p>4. Iterative development process – Select design level, approach, dimensions and tests the model iteratively.</p> <p>5. Transfer concept & Evaluation – Publications, software tool, etc.</p> <p>6. Implementation of transfer media- Target media in phases depending on the users. Release of voluminous documentation</p>	<p>1. Suggested Stage model – is based on developer’s perspective; based on literature review and ideas from practitioners.</p> <p>2. Conceptual model – Maturity levels and detailed description are developed. Empirical methods i.e. case studies are adopted.</p> <p>3. Theoretical model – Theories explain levels, descriptions, relevance and path of evolution. Dimensions are derived theoretically and validated via focus groups.</p> <p>4. Empirical model - Each dimension is assigned numerical value and interrelated to a particular maturity level. A survey instrument for testing the model.</p> <p>5. Revised stage model – Compare the empirical model results with reality and revise model accordingly.</p>

<p>6. Maintain – If acceptance is achieved, design to handle volumes.</p>	<p>first or self-assessment questionnaires.</p> <p>7. Evaluation of results – This determines validation of the maturity model in reality.</p> <p>8. Iterative Continuation – Outcome of evaluation decides rejection, otherwise improve continuously.</p>
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I.Appendix.2 Vocabulary and Guidelines

Table 2: Vocabulary and guidelines while designing and developing constructs.

Concept	Characteristics	References
Name, Acronym, source	Basic details of the models. E.g. Capability maturity Model, CMM, Software Engineering Institute –USA, 1991 to 1993	[26]
Focus of Model	<i>General or domain specific</i> . Define the domain, problem definition and relevance first. Need must be demonstrated backed by evidence.	[12], [3]
Entity to Maturation*	Usually an Object that is at the centre of analysis and the context in which it is applied*. Object is <i>people, process, technology or no clear distinction</i> .	[26]
Stakeholders	Development by <i>Academia, Practitioners, Government or combination</i> .	[11]
Unit of Analysis	Usually at a level of <i>technology, process or organisations</i>	[11]

<p>Respondents</p> <p>Target Audience</p>	<p>Provide empirical evidence. E.g. Partners and owners, Higher management (CEO, CIO, etc.), depending on the focus of the model.</p> <p>Are the ones who would use the Maturity model e.g. Auditors, partners, higher management, managers, classified as <i>Management oriented or technology oriented</i>.</p> <p>Book, Journal, Webpage, etc. Detailed documentation reveals the rigor.</p>	<p>[11]</p> <p>[26]</p> <p>[11],</p> <p>[26]</p> <p>[38]</p>
<p>Documentation</p>	<p>The basic structure for the model.</p> <p><i>CMM-like, Likert-like questionnaires, Maturity Matrix or grids.</i></p> <p><i>Nolanisue-like or stage of growth model.</i></p> <p><i>Focus area model.</i></p> <p>Is the model verified and validated? Verification represents testing phase; test the model on a sample for accuracy.</p> <p>Validation is the degree to which the model represents reality. This is normally done after the model is published. Can the model be refaced from time to time to fit the context?</p> <p>Most of reviewed models in “IS” follow a linear, unidirectional path from lower maturity to higher maturity.</p> <p>Dominant problems are predictable primary concerns that the entity under maturation would face for each theorized stage.</p>	<p>[26]</p> <p>[9]</p> <p>[40]</p> <p>[26]</p> <p>[3], [26],</p> <p>[23]</p> <p>[30],[10]</p> <p>[39],</p> <p>E.g.</p> <p>[18], [9]</p>
<p>Design Factors</p>	<p>Composition</p>	<p>Reliability</p> <p>Mutability</p>
<p>Representation</p>	<p>Path of Maturation</p> <p>Dominant problems</p>	<p>Representation</p>

		[11]
	Representation of Maturity	<p>1. <i>Level of abstraction</i> – Corporate, Management or staff. Higher the level of abstraction lowers the number of dimensions.</p> <p>2. <i>Number of Stages or levels</i>– Is mostly around 4 to 6, depending on the model and its purpose. E.g. Crosby grid (5), Nolan (4), CMM (5), and many more.</p> <p>3. <i>Stage fixed or Continuous</i> –Continuous models allow a scoring of characteristics at different levels; staged models require that all elements of one distinct level are achieved.</p> <p>4. <i>Numeric Value</i> –Maturity score depicted using numbers. Purpose of use is comparative i.e. benchmarking. The most common way of visualising is <i>Spider cobweb</i> design.</p> <p><i>Type 1</i> - Focus area maturity models (less popular)</p> <p><i>Type 2</i> - HSRM model and IS/ICT capability framework depicts benchmark variables/dimensions in the final representation of maturity. The user is left to comprehend overall maturity of the organisation (More popular).</p> <p>5. <i>Purpose of use</i> – Descriptive, prescriptive, comparative or combination.</p>
	Maturity levels	<p>E.g. [8], [30], [29], [31]. [34], [31], [6]</p> <p>[41], [40]</p> <p>[37], [26]</p> <p>[38]</p> <p>[30], [34]</p>
Constructs		

		Also termed as <i>Benchmark variables, process areas, Capability, and critical success factors</i> . <i>Cognitive capacity of users</i> – “Humans have limited cognitive capacities for memory, attention and perception”. Hence limit first level dimensions from 5 to 7.	[26] [21]
	Dimensions	These are second level variables on which the dimensions depend on. (Refer figure 2). E.g. BPMMM with 30 sub categories. DyAMM with 16 dimensions.	[12],[41]
	Sub-categories		
Assessment	Instantiation	<i>Self-assessment via Surveys</i> is most widely adopted instruments. Instantiation is mostly through web based software tool or an excel file. <i>Third party assessment or certifications</i> are other techniques applied in this case. E.g. CMM assessments are done by well trained and certified experts.	[11], [46], [26] [31]

*E.g. CMM is a process centric maturity model with software development process management at the centre of the model [31], BPMMM too is a process centric model [12], [10] is a technology centric; E-Government maturity model is a people centric maturity model [1].

I.Appendix.3 Classification of Methods and Instruments

Table 3: Classification of Methods and Instruments while designing and developing constructs.

Model & Approach	Methods			Instrument			Comments	
	Conceptual	Qualitative	Quantitative	Derivative	Survey**	Third Party*		Certification
Intranet Model [9]	•	•					None	Empirically derived using <i>interviews</i> and prior literature on stage models used to propose a model.
Analytics Maturity [10]	•							Developed through <i>anecdotal evidence and prior experience</i> . Surveys and interviews to collect information. Used by number of consultancy surveys on analytics.
Business-IT alignment [25]	•			•	•	•		Constructs derived from <i>literature</i> , questionnaire derived from <i>anecdotal evidence & experience</i> .
Social media Business [18]	•			•			•	Derived using <i>academic literature and consultancy maturity models</i> taking into account steps proposed by [39].
DyAMM [41]	•			•	•			Focus area maturity design. Proposed a new way of representing overall maturity in relationship with capability areas.
BI maturity model [23]	•	•	•	•	•	•		BI dimensions derived from existing literature, <i>Rasch algorithm</i> supported by cluster analysis used to derive maturity levels.
BI maturity	•	•	•			•		BI maturity and questionnaire derived from <i>literature, Rasch algorithm</i>

model [34]									supported by cluster analysis to derive maturity levels.
BI Maturity [36]	•			•					Questionnaire of the existing BI MM [35]. <i>Euclidean distance</i> to calculate Maturity level of an organization; formula from SOA model [28]
Business Process Maturity [12]	•	•		•					BPMM dimensions (5) from literature and case studies. <i>Delphi Method</i> adopted iteratively and <i>longitudinal case study</i> to evaluate model.
CMM [31] ***	•			•					Detailed and Comprehensive model built for practitioners.
Process Management in Hospitals [5]	•	•	•						Theoretical approach to define dimensions, revised via focus groups and relevant questionnaire developed. <i>Rasch analysis</i> to derive maturity levels.
Consumer Cloud Maturity [45]				•					Comparative overview of 9 existing Models, 1 academic paper (thesis) and rest white papers. CMMI structure referenced for 5 levels; not evaluated.
Social media Innovation [24]				•					Conceptual Maturity model; levels shown as <i>simple five percentiles</i> (5 stages i.e. 1 to 20%)
BI [16]				•					BI MM drew the structure, dimensions & relevant questions from a reputed consultancy and served for three consecutive surveys in 2004, 2006, 2009. <i>Simple addition & average</i> used to compare maturity.

*** CMM, CMMI are few developed for practitioners with dimensions drawn totally from industry experience.

**Survey as an instrument used and immediate feedback categorized as self-survey;

*Third Party – Includes assessment by researcher themselves.

I.Appendix.4 Maturity models through the lens of process theory

Table 4: Examples of Maturity models viewed through the lens of process theory.

Approach Model	Comments		
	Lifecycle	Evolutionary	Dialectal Teology
Intranet Model [9]	●	●	●
Analytics Maturity[10]	●	●	●
BITA [25]	●	●	●
SMBP [18]	●	●	●
DyAMM [41]	●	●	●

Each new stage represents a set of features that are superior to the old features, cumulative and unitary in nature; the article mentions an evolutionary approach with survival of intranet, however does not qualify under the classification of Van De & Poole [42]. There is a dialectal approach (e.g. to go from stage 1 to stage 2, the entity must have a sponsor, known as triggers, else it would stagnate at stage 1).

Single entity (use of analytics), however there are glimpses of contingency variables and one does not see a unitary path at least from stage 1 to stage 3. In addition, the objective is “competing on analytics” which invokes survival aspect of evolutionary approach. A dialectical thesis (e.g. motivation of leadership to stay in stage 2 or 3) is noticed.

Business IT alignment model by Luftman [25] is predominantly a lifecycle approach to maturity. Event progression is irreversible and linear. Dialectical approach similar to the above two models are used in form of enablers and inhibitors Business IT alignment.

Similar to Intranet model, however this model is very conceptual and is under the process of validation. Triggers are listed as dominant problems and follows a dialectical approach similar to the above three models.

● A Lifecycle approach to maturity - mostly a unitary, cumulative, and conjunctive sequence. Overall maturity can be seen through a teleological lens i.e. one can go to next level of overall maturity, only when the maturity of certain individual dimensions are achieved.

According to Van De Van and Poole [42], Life cycle theories are explained in terms of organic growth with an entity developing from its initiation to end state. The path of change is imminent to the entity, mostly a *unitary, cumulative, and conjunctive sequence*. Event progression is irreversible and linear and the driving force usually comes from within the entity. Evolutionary theories employ the mechanism of “competitive survival” to explain the evolution of species. Hence, *entities compete with similar entities for resources* [32]. Event progression *is recurrent, cumulative and probabilistic sequence of variation, selection and retention* [42]. Dialectic type of change drives on conflict theory as a driving force while teleology follows the logic of goal setting towards an envisioned state. Many would argue that Maturity models predominantly follow a teleological approach, wherein goals have to be met to move to the next stage, however we found only one i.e. DyAMM [41], that explicitly mentioned goals, therefore implying a teleological approach.

Reason(s) for selecting the above five maturity models as examples –

- ✓ **Intranet model [9] and SMBP [18]** were selected for two primary reasons i.e. (1) Even though they have not been cited widely, they were the only two maturity models published in BFI level 2 publications, (2) they follow a stage of growth modelling approach to developing a maturity model.
- ✓ **Analytics Maturity [10] and BITA [25]** - Business IT alignment maturity model was selected as both these undoubtedly one of the most accepted models for assessing Business-IT alignment both among academics and practitioners and is also very well cited. Similarly, Analytics Maturity [10], popularly known as Davenport’s DELTA score is very well known among academics and practitioners.
- ✓ **DyAMM [41]** – Finally Dynamic architecture maturity model was chosen for two reasons too i.e. (1) It gave the research community a new method of calculating a maturity score and visualizing overall maturity (2) It is the only maturity model published in the Scandinavian Journal of Information systems in the last 15 years.

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Paper II: A Methodological Demonstration of Set-Theoretical Approach to Social Media Maturity Models Using Necessary Condition Analysis

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A Methodological Demonstration of Set-Theoretical Approach to Social Media Maturity Models Using Necessary Condition Analysis

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Abstract

Despite being widely accepted and applied across research domains, maturity models have been criticized for lacking academic rigor, especially methodologically rigorous and empirically grounded or tested maturity models are quite rare. Attempting to close this gap, we adopt a set-theoretic approach by applying the Necessary Condition Analysis (NCA) technique to derive maturity stages and stage boundaries conditions. The ontology is to view stages (boundaries) in maturity models as a collection of necessary condition. Using social media maturity data, we demonstrate the strength of our approach and evaluate some of arguments presented by previous conceptual focused social media maturity models.

Keywords: Maturity Models, Social Media, Necessary Condition Analysis, Stage of Growth Models.

II.1 Introduction

Maturity models are nested in IS research and in particular, IT practitioner communities. Being normative and prescriptive by nature, lacking theoretical solidity, methodologically rigor and empirical validation maturity models is an ongoing battle field for debate and fierce critique in IS research (King and Kraemer 1984b; Lasrado et al. 2015) and related disciplines (Andersen and Henriksen 2006; Wendler 2012). Maturity models in IS are understood as tools that facilitate internal and/or external benchmarking while also showcasing future improvement and providing guidelines through the evolutionary process of organizational development and growth (Lasrado et al. 2015; Mettler et al. 2010).

Maturity can be defined as “the state of being complete, perfect or ready” (Mettler et al. 2010). In IS literature, the most common maturity models are termed as stage-growth models and the concept has been employed to develop an understanding of evolution of information systems. While Nolan and Gibson (1974)’s stage model is considered a landmark reference and the quality grid proposed by Crosby (1980) has influenced researchers in IS domain (Pöppelbuß et al. 2011), maturity models became mainstream with Capability maturity model (CMM) developed by Paulk et al. (1993) for software processes in the 1990’s.

Despite being widely accepted and applied across domains, maturity models have been criticized for lacking academic rigor (King and Kraemer 1984a) as well as practical relevance (Wendler 2012). Another criticism has been the sheer number of the conceptual maturity models that do not use scientific empirical methods during the design process (Lasrado et al. 2015). The reason for this acceptance and criticism lies in its very nature i.e. it gives a simplistic reductionist view of a complex problem, thus creating awareness on competences and offering a tangible way to assess an organization’s practices (Jugdev and Thomas 2002).

However, literature on maturity models design and evaluation in IS till date, barring a few exceptions (Becker et al. 2009; De Bruin 2005; King and Kraemer 1984b; Lahrmann et al. 2011; Pöppelbuß and Röglinger 2011; Solli-Sæther and Gottschalk 2010), have focused solely on criticising the inherent and known nature of maturity models than providing viable solutions to improve their rigor. Therefore, the aim of this paper is to address some of the criticisms mentioned above in past research. Specifically, this paper addresses the research question of *how can maturity stages and boundaries conditions be derived by using scientific empirical techniques?* In

order to answer the research question, this paper proposes a set-theoretic approach for designing maturity models based on the method of Necessary Condition Analysis (Dul 2016c). We argue that maturity stages can be conceptualised in terms of necessary conditions (i.e. absence of these causes the entity under maturation to fail) and demonstrate this in the context of social media maturity models.

The rest of the paper is organized as follows. First, we examine the existing literature on maturity models in general, social media maturity in particular and identify key research gaps. Second, we present the method of Necessary Condition Analysis (NCA) drawn from set theoretical approach to social sciences (Dul 2016c; Ragin 2008; Wagemann and Schneider 2010) an approach that can be applied while defining maturity levels or stages. Third, we present the dataset, discuss the data analysis process and rationale and the application of NCA in the domain of social media maturity models. Fourth, we present our research findings and their significance. Fifth we discuss the steps in detail and demonstrate them by identifying stage boundary conditions for social media maturity in customer facing and innovation activities. Sixth and last is the conclusion and future research agenda.

II.2 Prior Research

II.2.1 Maturity Models in IS: Characteristics of a Maturity Model

A number of academic disciplines use the term “maturity” in a comparative sense, while developing maturity models as classification schemes (Andersen and Henriksen 2006). The purpose of maturity models has been diverse with many using it as a measure used by organizations to evaluate their capability in a particular domain or problem area (CMMI 2010); with the model providing the construct or structure representing maturity (De Bruin et al. 2005) and others to outline the path of entity towards maturation, including defining the stages and relationship between them in the form of stage models (Becker et al. 2009). This diverse nature of use, positions maturity models in between methods and models (Mettler 2009; Pöppelbuß et al. 2011), with an assessment instrument enabling benchmarking between participants and providing a roadmap for future progress.

A maturity model usually consists of a sequence of maturity stages (Raber et al. 2012), mostly four or five (Karkkainen et al. 2011). Each stage expects the entity (people, process, technology, organisation etc.) under maturation to fulfil certain requirements that constitute that particular stage (Poeppebuss et al. 2011). Usually, this is

determined by defining critical success factors and boundary conditions. The critical success factors as prescribed by the maturity model also mean better outcomes and thus higher business benefits (value) as the organization progresses on the path to increased maturity. In general, maturity assessment is understood as a “measure to evaluate the capabilities of an organization”(Raber et al. 2012), with an underlying assumption of a single linear path to maturity as shown in Figure 1.

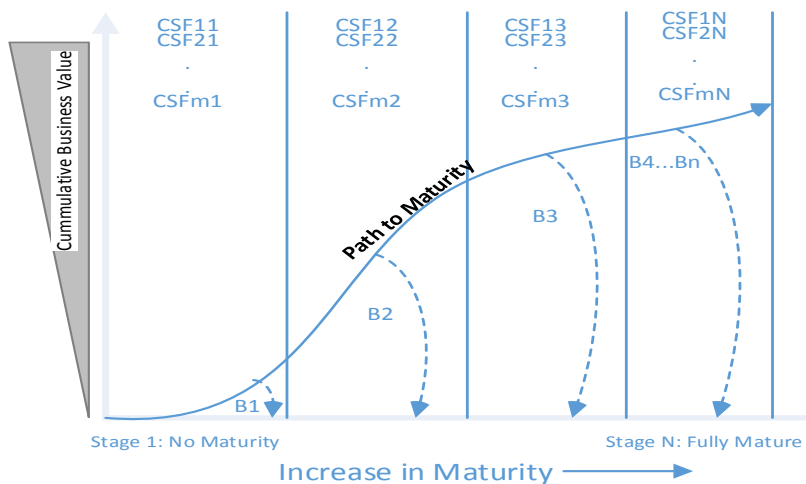


Figure 1: Critical success factors (CSF) and boundary conditions in maturity models.

Critical Success Factors (CSF_{mn}, m factors and n stages): “Dimensions”, “Factors”, “Benchmark Variables” and “Capabilities” are some of the other terms used for critical success factors (Lasrado et al. 2015). CSF’s describe multidimensional factors that decide the entities maturity stage. Each CSF is also further classified into a number of sub-factors with specific characteristics at each stage (Raber et al. 2012).

Boundary Conditions or Triggers [B1... Bn]: Boundary conditions, also termed Triggers, are very specific conditions (usually a subset of CSF’s) that the entity has to satisfy in order to progress from one stage to another. Without satisfying the boundary condition, an entity cannot progress further irrespective of satisfying all other conditions. For example, in the case of intranet maturity models (Damsgaard and Scheepers 1999), active support of a technology champion or a sponsor from the top management team is a boundary condition to progress from stage 1 to stage 2.

Figure 1 briefly summarizes the important characteristics of a maturity model. For the purposes of this paper, we focus our attention on the boundary conditions and conceptualise them as necessary conditions from a set-theoretical approach. In order to do that we have selected the emerging theme of social media maturity as discussed in the next section.

II.2.2 Social media maturity models

Social media is a collection of applications that include blogs, social networking sites and multimedia sharing sites or as defined by Kaplan and Haenlein (2010) “a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, and that allow the creation and exchange of User Generated Content”. According to Werder et al. (2014) most of the organisations have adopted and applied social media applications for branding, marketing, sales, customer service and support, and other business activities with an objective of increasing brand loyalty, revenue, customer satisfaction and decreasing operational costs. This positive trend has resulted in a number of maturity models being proposed especially by consultancies: Deloitte (Kane et al. 2014), Forrester (Li and Bernoff 2011) and many more proposing improvements and providing guidelines towards success media success. However, all the models are mostly conceptual and lack documentation of strong empirical evidence and the design process, with the sole exception of the social business maturity assessment by Deloitte (Kane et al. 2014).

Academic IS literature on the other hand too had only four social media maturity models which were rigorously analysed and only one being empirically validated (Table 1). These four models had wide diversity in terms of business processes and employed different conceptualizations of maturity. The focus of Duane and O'Reilly (2012) was SME's in Ireland using social media for PR & Sales. Lehmkuhl et al. (2013) and Karkkainen et al. (2011) looked at social media maturity for innovation related processes in organisations. While these three models looked at social media maturity from a strategic perspective, Geyer and Krumay (2015) proposed social media management maturity from an operational perspective. Further, the conceptualisation of maturity was different with Duane and O'Reilly (2012) taking inspiration from Nolan and Gibson (1974)'s stages of growth approach, while Lehmkuhl et al. (2013), Karkkainen et al. (2011) and Geyer and Krumay (2015) adopt a practical matrix approach inspired by Crosby (1980). There was significant overlap of critical success factors between the four maturity models as listed in Table 1: IT security, employee access, strategy, governance, empowered employee and many others.

It is however worth noting that even though all four models acknowledged recent papers on model development (Becker et al. 2009; Mettler 2009; Solli-Sæther and Gottschalk 2010), only one maturity model (Duane and O'Reilly 2012) provided a theoretical justification for the stage boundaries. However, no empirical evidence was included to justify the theoretical conceptualisation of the boundary conditions in both

the original and subsequent papers (Duane and O'Reilly 2015). Situated in this academic context, we propose the adoption of a novel method called Necessary Condition Analysis (NCA) that can be used by maturity model designers to both conceptualise as well as empirically evaluate the critical success factors (CSF's) and boundary conditions.

Table 1: Conceptual Social Media Maturity Models: Empirical Validation, Scope, Intended Users, Characteristics, and CSF

Authors	V	Scope, Intended Users, Characteristics, Critical success factors
Karkkainen et al. (2011)	N	<ul style="list-style-type: none"> • Social media for innovation activities. 5 Stages, 5 CSF's, No boundary conditions. • Level of integration in innovation processes, social media practices are structured, information security and incentives are institutionalised, and skills are recognised & resources employed.
Duane and O'Reilly (2012)	Y	<ul style="list-style-type: none"> • Social media business profile primarily for PR, Sales and marketing activities. SME's in Ireland. 5 Stages, 10 CSF's, 24 boundary conditions (dominant problems). • Strategy, empowered employees, dedicated leadership, active new social channels, selected access to staff, dedicated resources, internal social media skills and measuring ROI has a linear positive impact on maturity and business value.
Lehmkuhl et al. (2013)	N	<ul style="list-style-type: none"> • Social media adoption for innovation activities. 5 Stages, 5 CSF's (17 sub-conditions), 12 boundary conditions out of 17 sub-conditions. • Strategy, governance, social data analysis, top management support, employee access, employee usage, and workflows.
Geyer and Krumay	N	<ul style="list-style-type: none"> • Social media operations across an organisation. No Stages yet, 3 pre-conditions, 6 CSF's.

(2015)		<ul style="list-style-type: none"> Operational social media management process, human resource management, social listening & monitoring, social media & data integration, social media strategy, and policy & operational guidelines.
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Note. V- Validated, *Y – Yes, *N- None/No

II.3 Methodology - Necessary Condition Analysis (NCA)

In this section, necessary condition analysis is discussed as a method to empirically evaluate the boundary conditions in a stage-growth maturity model. As described in Figure 1 earlier, an entity under maturation has to satisfy boundary conditions in order to progress to the next stage in the maturity model. Logically, these conditions can be categorised as “necessary but not sufficient” (Ragin 2008). That is, the absence of the necessary conditions guarantees failure in terms of progression to the next stage of the maturity model. Traditional variance based (e.g., correlation or multiple regression) approaches are not appropriate for testing or inductively deriving such conditions (Dul 2016c; Ragin 2008; Wagemann and Schneider 2010). While the fuzzy set theory based qualitative comparative method pioneered by Ragin (2008) is a more established alternative, it mostly focuses on sufficient but not necessary configurations (Dul 2016a). Therefore, given the requirements of this study, we explore a recent method called Necessary Condition Analysis (NCA).

NCA is a methodology for identifying necessary conditions in data sets (Dul 2016c) be it categorical or continuous in nature. Necessary conditions are:

“factors that produce desirable outcomes, factors that enable outcomes (i.e., that are necessary for the outcome to occur). A necessary condition is a condition that must be present to enable a certain outcome; without the condition, the outcome will be absent” (Dul 2016c; Wagemann and Schneider 2010).

For example, in a dichotomous situation (figure 2a), “the independent variable (the necessary condition) and the dependent variable (the outcome) are either absent or present” (Dul 2016a). Identifying a necessary condition (i.e., X is necessary for Y) requires no data points in the upper-left corner of the X-Y plot: X (condition) is absent (0) and Y (outcome) is present (1). The combinations X=0, Y=0 and X=1, Y=1 illustrate the presence of a necessary condition; X=1, Y=0 is irrelevant as X is not sufficient for Y (Dul 2016c; Wagemann and Schneider 2010). The same criteria of no

data points in the upper-left corner is extended to figure 2b and 2c in case of categorical and continuous data sets respectively.

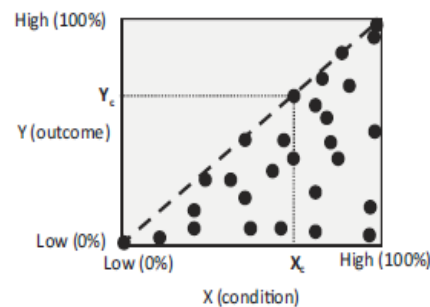
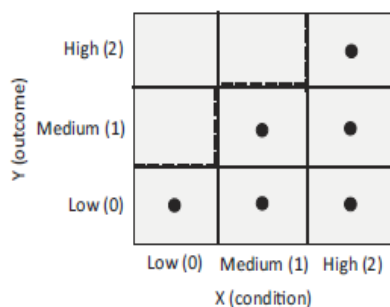
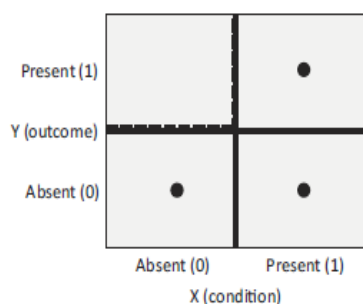


Figure 2a: A dichotomous necessary condition (Dul 2016c)

Figure 2a: A dichotomous necessary condition (Dul 2016c)

Figure 2a: A dichotomous necessary condition (Dul 2016c)

In reality however, the distribution of the X-Y plot is not so symmetrically distributed from the centre. The measure of necessary conditions is calculated by drawing a ceiling line wherein the upper-left part of a scatterplot is separated from the lower-right by a line between the area with and without data points. To draw ceiling lines, various techniques are prescribed and in the R package prescribed (Dul 2016b) for NCA, ceiling envelopment is created on the basis of Data Envelopment Analysis (DEA) techniques from the operations management domain (Dul 2016c). Dul (2016c) suggests a piecewise linear ceilings with free disposal hull technique (CE-FDH) or a ceiling regression with free disposal hull (CR-FDH) as “they generally produce stable results with relatively large ceiling zones”. The strength of the necessary condition is evaluated in terms of the effect size, i.e., “the constraint that the ceiling poses on the outcome” (Dul 2016c) and its characteristics have been listed in Figure 3.

- Larger the ceiling zone, lower the ceiling line, larger is the ceiling effect, and therefore larger the effect size of the necessary condition.
- The effect size (d) = C/S , where C is the size of the ceiling zone, and S is the scope. The scope (S) is calculated based on either theoretical or observed minimum and maximum values of X and Y : $S = (X_{max} - X_{min}) / (Y_{max} - Y_{min})$.
- Effect size (d) can be interpreted similar to R^2 in regression analysis i.e. the necessary condition effect size ranges from 0 to 1.
- Necessary condition is valued as important or not depending on the effect size, context as well as theoretical arguments and practical common sense.

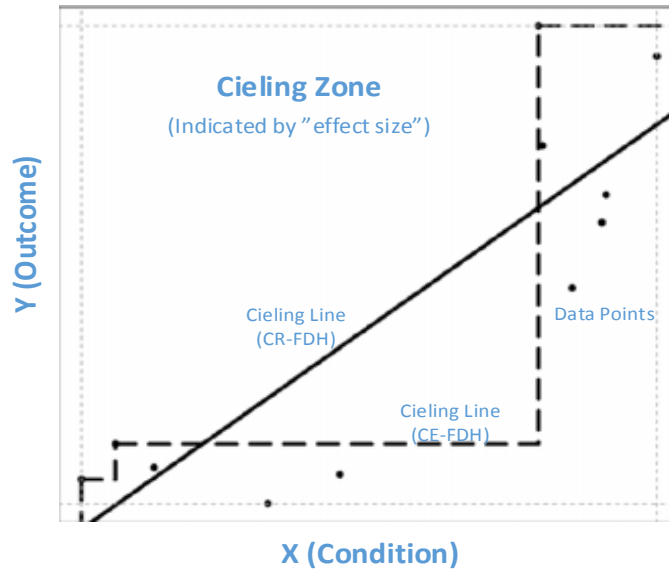


Figure 3: X-Y Plot, Ceiling Zone, Effect Size and Necessary Condition Analysis (Dul 2016c).

Dul (2016c) further suggests a general benchmark for the size of an effect: $0.0 < d < 0.1$ as a “small effect,” $0.1 < d < 0.3$ as a “medium effect,” $0.3 < d < 0.5$ as a “large effect,” and $d > 0.5$ as a “very large effect”. Furthermore it is suggested to use effect size 0.1 as the threshold as “any necessary condition hypothesis in the continuous case (X is necessary for Y) is rejected if the effect size d is less than 0.1” (Dul 2016c). We adopt the above suggestions in our data analysis as discussed in the next.

II.4 Dataset collection, selection and analysis

II.4.1 Data Collection

The NCA method was applied to a subset of the dataset focusing on social media developed by Networked Business Initiative (NBI)⁵². NBI measured digital maturity of organizations in Denmark in terms of five digital technologies and measured 231 organizations. The targeted audiences are managers (top and middle management) in Danish organizations looking towards comparing their digital performance against their peers. Due the limited data availability till date, we limit the scope to customer facing activities (i.e. Sales & marketing and PR) and innovation activities, thus using sample of 86 organizations (Appendix 1 & 2). The data was collected through a cross-sectional survey linked to a live dashboard whose primary purpose was comparative

⁵² Networked Business Initiative (NBI): Benchmarking maturity of Danish organizations (www.networkedbusiness.org)

benchmarking of participating organizations in Denmark. Given the page constraints, we do not go into the depth of the dataset, but list out key facts and briefly list the CSF's (Table 2) relevant for this paper.

Outcome(s): Business value delivered in PR as well as Sales and Marketing is calibrated as an outcome in analysis 1 (N=86). Business value is measured using a 5-point Likert scale (0 to 4) for each of the business processes separately. In the case of measuring maturity for customer facing (promote & sell) activities, a simple average is used. For example, if Organization A has realised some business value (2) in PR and no business value (0) in Sales and Marketing, then the outcome is calibrated as $Y = (2+0)/2 = 1$.

Boundary Conditions: There are 17 CSF's identified for achieving maturity in customer facing (promote & sell) activities. However, for social media maturity in innovation related activities, in addition to the 17 CSF's, both the extent of use of social media in promotion and selling as well as business value realization are two additional necessary conditions. This hypothesis is also supported by existing social media maturity models literature: Duane and O'Reilly (2012) and Kane et al. (2014). Given the page limit of this paper, we do not go into the specific details of every CSF but list the most important examples.

Table 2: Critical success factors and outcomes of NBI social media maturity survey.

Condition or CSF (X)		Abbreviation; Scale; # of items
Management	Top Management encourages the use of social media throughout the organization, while having digitalisation as priority in the past and future.	TMT; (0-4); 3
	IT investment within the organization as compared to previous years, understanding the intention of management towards digitalization.	INV; Ordinal scale (0=decreased,1=Same, 2=increased) ; 1
	Digital strategy Index ⁵³	DS; (0 to 4); 1

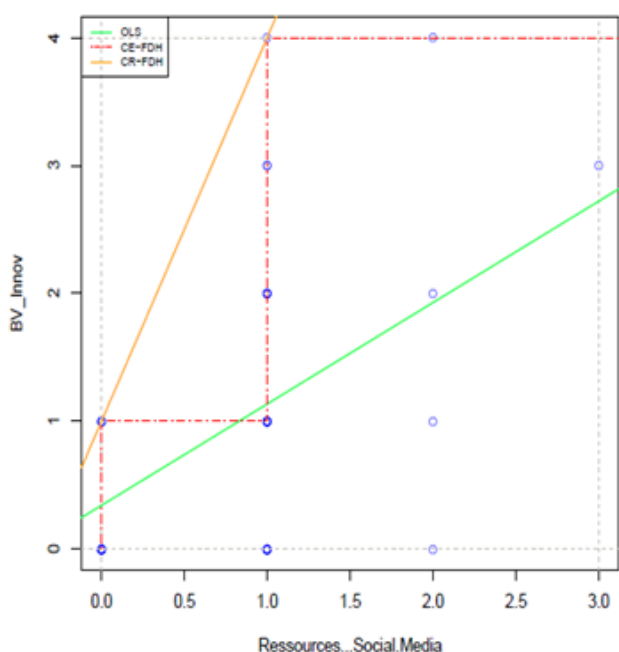
⁵³ The criterion for this index is the presence or absence of an overall digital strategy (measured as Yes/No), the extent to which this policy has been aligned with the company strategy, communicated and implemented across the company (measured using a 5-point Likert scale from 0 to 4). For example, if Organization A has no digital strategy (X1=0) then the index is calibrated as 0. Organization B however has digital strategy (X1=1), has been aligned fully (X2=4), has been communicated largely (X3=4) and implemented to a small degree (X4=2). The digital strategy index for organization B is $(X1+X2+X3+X4)*4/13 = 3.384$, wherein 4 is calibration range and 13 is actual scale range. IT security index is also calculated in the same manner.

IT Policy	Allowing access to Own devices (OD) measured on access to number of systems, and/or providing employees with devices (PEWD) measured on number of employees, while having a high IT security index (ITS) is considered as an organization with high social media maturity.	ITS; (scaled to 4); 1
		OD; (0-4) ; 1
		PEWD; (0-4) ; 1
Technology	Social media presence, measured as the number of social media channels.	ESC; Count (0 -8) ; 1
	Extent of Use of social media, measured as an average of PR and Sales & Marketing	U; (0-4) ; 2
	Number of resources (FTE) hired specifically for social media activities, measured as none, part time, full time and more than one. Sometimes, a sole manager manages social media. Hence NBI also measured professional skills (S) available inside the organization that can manage social media.	FTE; Ordinal (0,1,2,3) ; 1
		S; (0-4) i.e. Not at all to Very high degree; 1
Metrics (M) is a measure of formalized social media activities. It is measured through the presence of either KPI's, workflows or both.	M; Ordinal (0,0.5,1) ; 2	
Culture	The measures for Culture were based on an organization orientation towards employee empowered style of working and an explorative culture wherein new IT systems are always sought after (EEC), a well-planned and structured style (PSC),. These were based on a factor analysis of seven items measured on 5 point scale i.e. Completely disagree (-2) to Completely agree (2).	EEC; (-2 to 2) ; 5
		PSC; (-2 to 2) ; 2
Y	Business Value from social media in customer facing activities measured as an average of PR and Sales & Marketing	BV; (0-4) ; 2
	Business Value from social media in innovation activities	BV-Innov; (0-4) ; 1

In addition to the above 4 more conditions were measured by NBI as part of the survey of which 3 (# of IT systems, # of internal online communication channels, IT training) all of which is measured as their number count and one i.e. IT Skills within the organisation is measured similar to Digital strategy Index. Now that all the conditions (CSF's) and the outcome (business value) have been explained, we go ahead and apply the method of NCA on our dataset and present our findings in the next section.

II.5 Results

To determine if a given CSF was in fact a necessary condition, we employ the bivariate approach and plot the calibrated value to each CSF against the calibrated value assigned to the outcome (business value) on an X-Y scatter plot. This is done using the R software package for NCA (Dul 2016b), specially to draw the ceiling lines and calculate effect sizes. As discussed earlier an effect size of 0.1 is considered as threshold and any necessary condition hypothesis below that is rejected. Furthermore, as discussed earlier (section 3.1.2) depending on the CSF measure (i.e. dichotomous or continuous) and the interpretability of the results, the type of ceiling line (i.e. CE-FDH, CR-FDH or any other) is selected. This concept is further explained using figure 5.



Unsure Zone: In some situations, it is difficult to interpret results using the ordinary linear regression ceiling line (CR-FDH). For instance, consider a situation in which to realise 30% Business value at least 2.2% of maximum (3-5 resources) is necessary. In such situations CE-FDH makes more sense as one part time resource (33.33% of maximum) is necessary to achieve 30% or more business value from using social media for innovation related activities.

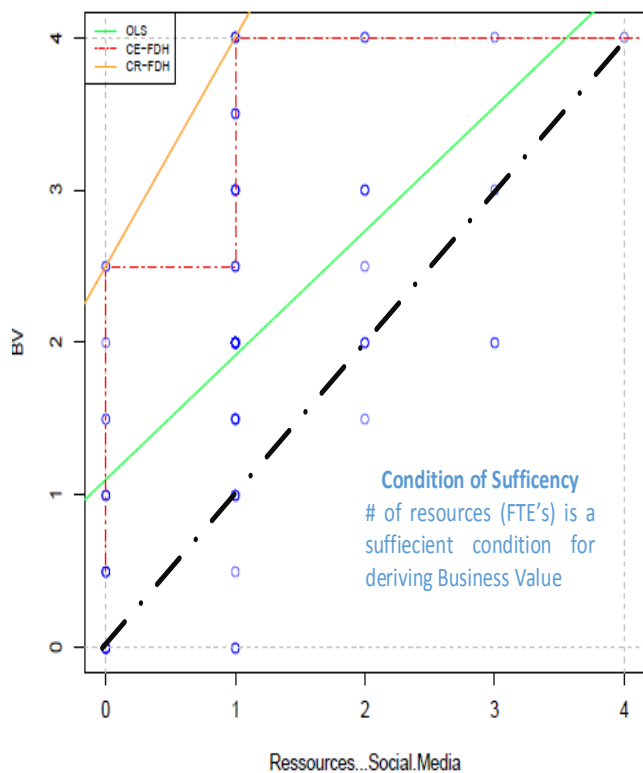
Y (BV-Innov) (%)	FTE's (%)	FTE's	(FTE's) (%)	FTE's
0	NN	NN	NN	NN
10	NN	NN	NN	NN
20	NN	NN	NN	NN
30	33.3	Part Time	2.2	
40	33.3	Part Time	6.7	
50	33.3	Part Time	11.1	Unsure
60	33.3	Part Time	15.6	Zone
70	33.3	Part Time	20.0	
80	33.3	Part Time	24.4	
90	33.3	Part Time	28.9	
100	33.3	Part Time	33.3	Part Time
Effect Size	0.250		0.125	
	Medium Effect		Medium Effect	
Ceiling Line	CE-FDH		CR-FDH	

Figure 5: Rationale for type of ceiling lines based on the variables (continuous vs. discrete).

Using CE-FDH it is logical to interpret that hiring a part time resource to work on social media is found to be a necessary condition for delivering greater than 20% of the business value in innovation related activities. However, while using CR-FDH, it becomes very difficult to interpret the results as shown and explained in figure 5. Therefore, in our analysis (see appendix 1 & 2 for details), we have used CE-FDH when the condition is discrete (e.g. number of systems, channels, resources, etc.).

From the results in appendix 1, it could be concluded that only three CSF's (# of external social media channels, extent of use, and an employee empowered culture) are termed as necessary conditions for delivering business value using social media in customer facing activities. In addition, we also found one condition of sufficiency as

illustrated in figure 6. When one inverts a necessary condition, a sufficient condition is obtained (Poon et al. 2011). By definition, a sufficient condition “ensures the existence of the outcome (i.e., if $X=1$ then $Y=1$). But the outcome can also exist without the sufficient condition (i.e., if $X=0$, Y can still be 1)” unlike a necessary condition (Ragin 2008). In our case, as shown in figure 6, we can interpret that if an organization has hired a dedicated resource (i.e. even part time) to handle social media operations, then the organization has already realised some level of business value (benefits) from its use of social media for promotion and selling activities.



Not Necessary: Using the CE-FDH ceiling approach, an effect size of 0.094 is calculated showing that number of dedicated resources hired to be a non-necessary condition for deriving business value.

Not Fully Sufficient: The bottom right of the X-Y scatter plot is almost empty indicating that # of resources hired is a sufficient condition for achieving business value. It is not a fully sufficient condition as there are 3 exceptional cases wherein presence of a part time resource has failed to produce the outcome (i.e. at least some business value)

Y (Business Value)	Very High ($Y > 80\%$)	0	8	4
	High ($50\% \leq Y \leq 80\%$)	3	9	5
	Low ($20\% < Y < 50\%$)	11	29	6
	No Value ($Y \leq 20\%$)	8	3	0
	N= 86	None	Part time	One/More
		X (# of resources or FTE's)		

Figure 6: Condition of Sufficiency - Presence of part time resource indicates that at least some business value w.r.t promoting & selling activities.

On the contrary, our results for social media maturity for innovation related activities (appendix 2) has nine out of the seventeen CSF's termed as necessary conditions for delivering business value. In fact, two of these CSF's (top management support and # of external social media channels) are considered to have a large effect on the outcome which supports the conceptual arguments presented by both Karkkainen et al. (2011) and Lehmkuhl et al. (2013) in their respective social media maturity models for innovation processes. Furthermore, we found that extent of use and the business value realised in customer facing activities are also necessary conditions for realising business value in innovation related activities. These results provide empirical evidence to the conceptual arguments by Duane and O'Reilly (2012) and Li and Bernoff (2011) in their respective social media maturity models at the organizational level in general.

In this section, we found that there are 3 and 11 necessary conditions for realising business value by using social media in promotion & selling activities and innovation related activities respectively. In the next section, we discuss these findings and present an approach to derive "stage boundaries" of a maturity model using the bottleneck table from NCA (see Appendices 2 & 3 for details).

II.6 Discussion

II.6.1 Towards an Empirical Approach to Stage Boundary Conditions for Maturity Models

We have demonstrated that boundary conditions in a maturity model can be conceptualised and empirically evaluated as "necessary conditions" and that all conditions need to be satisfied to progress further to the next stage. Moreover, these boundary conditions are in many cases a subset the of critical success factors (CSF's). We have applied Necessary Condition Analysis (NCA) to single antecedents (bivariate approach) separately. However, there are multiple antecedents to maturity and therefore we interpret these necessary conditions using the bottleneck table.⁵⁴ We propose the following steps for deriving the stage boundary conditions and demonstrate their application:

Step 1: Define the basic characteristics of the maturity model (i.e. focus, audience, CSF's, assessment tool and the unit of analysis). In our case (NBI dataset), the

⁵⁴ NCA's "bottleneck table is a representation of the ceiling multiple antecedents (multivariate approach). In the multivariate approach, all conditions need to be put in place to prevent failure" (Dul 2015).

characteristics are: focus is social media maturity, the audience is organisations in Denmark, 17 CSF's, self-assessment via online survey and the unit of analysis is business process.

Step 2: Clearly and explicitly state the underlying assumptions to maturity. Moreover, if one is using a proxy for measuring maturity it should be stated. In our case, we listed our assumptions clearly in section 4.1 and use business value (Y) as a proxy for maturity.

Step 3: Communicate all the CSF's and outcomes (section 4.2). In our case, we had 17 CSF's and 2 outcomes⁵⁵.

Step 4: Run NCA and identify all the necessary conditions (section 4.3). Use effect size (d) of 0.1 as minimum threshold. In our case, we identified 3 and 11 necessary conditions.

Step 5: Present all necessary conditions results (i.e. descriptive statistics, ceiling lines, effect size, and significance of the effect) and the bottleneck table⁵ as shown in appendix 1 & 2.

Step 6: Define the maturity stage boundaries using bottleneck table as reference. Find meaningful theoretical or practical reasoning to support the stage boundaries. In our case we derive 4 maturity stages [i.e. Very High ($Y > 80\%$), High ($50\% \leq Y \leq 80\%$), Low ($20\% < Y < 50\%$), No Value ($Y \leq 20\%$)]. We use the calibration logic used by Fiss (2011), Ragin (2008) and others in configurational techniques wherein the minimum threshold is marked at 50% and the outcomes above that are divided as high and very high respectively. In addition, we further split the lower half into two stages as we find a significant difference among the necessary conditions at $Y \leq 20\%$ and $Y > 20\%$.

Table 3: Stage Boundary Conditions in Customer Facing (Promote & sell) Activities

CSF (Boundary Conditions)		Social Media Maturity (PR, Sales & Marketing Activities)			
		No	Low	High	Very high
Extent of use	Promotion & Selling Activities		Small degree of use.	Some to high degree of use.	Very high degree of use is necessary

⁵⁵ Given that our unit of analysis was at a "business process" level, we analysed the 2 outcomes separately.

Social Media Presence	Facebook, twitter, YouTube, etc.	Presence on one of the social media channels is necessary.	Presence on two channels is necessary.
Culture	Employee Empowered		Necessary for high business value.

Step 7: Populate the boundary conditions (necessary conditions) to their respective stages as illustrated in table 3 and table 4. For example, while presence of one social media channel (X=12.5%) is considered necessary to realise anywhere between none to high business value (i.e. $10\% \leq Y \leq 80\%$) in customer facing activities, the organisation has to increase its presence to two channels (X=25.5%) in order to realise very high ($Y > 80\%$) business value.

Step 8: Finally, explicitly list the managerial implications of not satisfying these necessary conditions. For example, as shown in table 3, for an organisation to realise high business value (maturity stage 3) through use of social media in innovation related activities, 8 stage boundary conditions (table 4) have to be met. Failure to satisfy even one of those necessary conditions would keep the organisation at stage 2 (low maturity). For example, an organisation at stage 3 is expected to provide its relevant employees with a device (i.e. laptop, mobile), while allowing employees to access some of company IT systems through personal devices and at the same time having an IT security policy in place.

Table 4: Stage boundary conditions in Innovation (R&D) related activities

CSF (Boundary Conditions)	Social media maturity w.r.t Innovation activity →			
	No	Low	High	Very high
Top Management support	Social media use to be initiated with regards to innovation related activities in an organisation.			
Number of resources (FTE's)		An organisation is required to hire a part-time resource so as to realise low to very high business value. Hiring one or more FTE is considered a non-necessary to realise higher level of business value.		
Extent	Innovation related		Small degree of use in	High degree of

of use	activities			necessary.	use is necessary.
	Promotion & Selling activities		Small degree of use is necessary.	Some degree of use is necessary.	Very high degree of use is necessary
Social Media Presence	Facebook, twitter, etc.	One channel is necessary.	Three channels are necessary.	At least three channels are necessary.	Five channels are necessary.
Culture	Employee Empowered			A necessary condition to realise high business value.	
IT Governance	IT security policy			A necessary condition to realise high business value.	
	Access to own systems(BY OD)		Access given to very few systems	Personal access given - some of the systems	Personal access given to most of the IT systems.
	Providing employees with devices			At least some people receive a device (mobile, laptop, etc.)	Most people receive a device from the company.
# of IT systems			Use of 1 IT system	Use of 2 IT systems is a necessary condition	
Business Value realised in Promotion and Selling activity			Realisation of low business value in PR, Sales & Marketing activities is a necessary condition		High Business value is a necessary condition.

II.6.2 Other Implications

Social media platforms create new forms of online public spheres (Robertson and Vatrapu 2010) and have greatly impacted the media and entertainment industry;

especially traditional media organisations such as newspapers, television and radio (Lugmayr et al. 2009). Lugmayr (2013) calls for media organisations to be regarded as holistic digital firms from an information systems (IS) perspective. Social media maturity models have an important role to play in that regard. Ideally, a social media maturity model should cover the diverse business functions of an organization such as operations, HR, sales and marketing, product development and innovation, IT, finance etc., and not be limited to customer facing activities. Further, it is important that social media maturity models encompass not only business-to-customer (B2C) companies but also public broadcasters, non-profit organisations, business-to-business (B2B), and business-to-government(B2G) organisations.

II.7 Conclusion and Future work

This paper applied NCA (Dul 2016c), to a social media maturity dataset. In the process of demonstrating the NCA method in the context of maturity models, the paper provides empirical evidence for some of conceptual arguments made in previous social media maturity models research. For example, we successfully validated the claim that only when business value is realized by using social media in customer facing activities (i.e. PR, marketing) can there be business value realisation in internal operations (i.e. innovation related activities) and that without top management support one cannot realise any business value in innovation related activities. The primary contribution of this paper is to conceptualize stage boundaries as necessary conditions and provide a systematic approach to empirically design and/or validate the stage boundary conditions. Furthermore, we believe that NCA in particular and set-theoretical approaches in general can successfully address most of the strong criticisms levelled at maturity models research in terms of academic rigor.

One major limitation of the NCA method employed is that it only identifies the level of CSF's that are required to progress to the next stage in the maturity model (i.e. necessary but not sufficient). However, our analytical approach in this paper ignores the CSF's (sufficient but not necessary) that also contribute to progress as absence of these CSF's are not a hindrance to progress to the next stage of maturity. We plan to address this limitation in our future work where a well-established analytical approach, fuzzy set QCA (Fiss 2011; Ragin 2008), would be applied in tandem with NCA. This would also allow us to conceptualize multiple paths to maturity, equifinality. Moreover, in future studies we would combine our findings for social media maturity in customer facing and innovation related activities, collect data for other business

activities (i.e. HR, service & support, leadership) and propose a holistic social media maturity model with the entire organisation as the unit of analysis.

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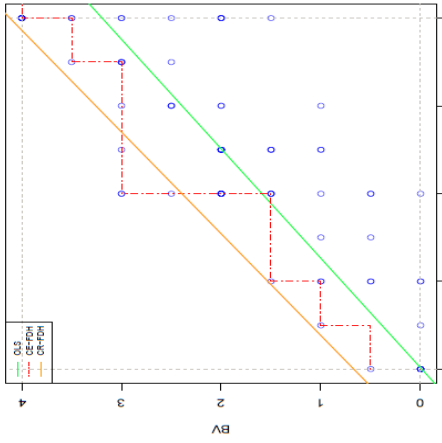
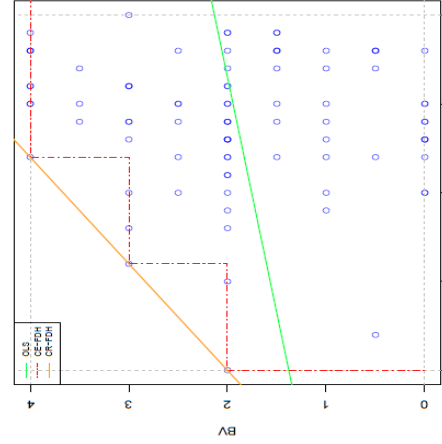
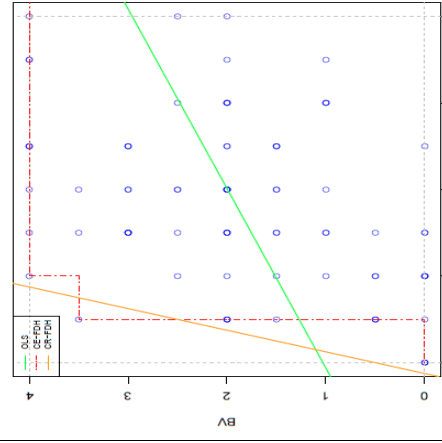
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II. Appendix-1: NCA and Bottleneck table for customer facing activities i.e. Promote and Sell (PR & Communications, Sales & Marketing).

Descriptive Statistics		Extent of Use Vs. Business Value	Employee empowered Culture Vs. Business Value	# of SM channels Presence Vs. Business Value			
Sample Size	86						
Unit of Analysis	Organisations in Denmark						
Business Process (Activity)	PR & Communication Sales & Marketing						
Company Size:							
1-2	15 (17%)						
3-14	29 (34%)						
15-49	13 (25%)						
50-249	23 (27%)						
Above 250	6 (7%)						
Orientation:							
B2C	13 (15%)						
B2B	43 (50%)						
B2B & B2C equally	28 (33%)						
Other	2 (2%)						
Founded Year:							
Before 2000	46 (53%)						
2001-2010	24 (28%)						
2011 onwards	16 (19%)						
Y Business Value (%)	Top Management support (%)	# of dedicated resources (%)	Skills of the resources (%)	Extent of Use (%)	# of IT systems (%)	# of SM channels Presence (%)	Employee empowered Culture (%)
0	NN	NN	NN	NN	NN	NN	NN
10	NN	NN	NN	NN	NN	12.5	NN
20	NN	NN	NN	3.8	NN	12.5	NN
30	NN	NN	NN	15.4	NN	12.5	NN
40	NN	NN	NN	27.0	NN	12.5	NN
50	NN	NN	NN	38.6	NN	12.5	0
60	NN	NN	NN	50.2	NN	12.5	5.7
70	NN	25.0	5.0	61.8	NN	12.5	11.4
80	11.1	25.0	11.7	73.4	NN	12.5	17.1
90	33.3	25.0	18.3	85.0	14.3	25.0	22.9
100	55.6	25.0	25.0	96.6	14.3	25.0	28.6
Effect Size	0.069	0.094	0.047	0.402***	0.018	0.141*	0.071
	Small Effect	Small Effect	Small Effect	Large effect	Small Effect	Medium effect	Small Effect
Ceiling Line	CR-FDH	CE-FDH	CR-FDH	CR-FDH	CE-FDH	CE-FDH	CR-FDH

The dashed line is a piecewise linear ceilings with free disposal hull technique (CE-FDH). The ceiling line technique i.e. CR-FDH (ceiling regression with free disposal hull) allows some data points above the ceiling line. The solid line is ordinary least squares regression line. Ceiling lines for 8 of the 17 necessary conditions of which only three have significant effect. The rest 9 conditions failed the condition of necessity.

II. Appendix-2: NCA and Bottleneck table for internal operations i.e. Co-create and Innovate (Innovation related activities).

Descriptive Statistics		BV (PR/Sales) Vs. BV (Innovation)				IT security Vs. BV (Innovation)				Access to own systems Vs. BV (Innovation)				# of IT systems Vs. BV (Innovation)			
Sub-set size (sample)	45 (86)	BV				IT Security				IT Security_Access own systems				X.IT systems			
Business Process (Activity)	Innovation (R&D)	BV_Innov				BV_Innov				BV_Innov				BV_Innov			
Company Size:	10 (22%) 16 (36%) 5 (11%) 12 (27%) 2 (4%)	BV_Innov				BV_Innov				BV_Innov				BV_Innov			
Market Orientation:	B2C B2B B2B & B2C equally Other	BV_Innov				BV_Innov				BV_Innov				BV_Innov			
Founded Year:	22 (49%) 12 (27%) 11 (24%)	BV_Innov				BV_Innov				BV_Innov				BV_Innov			
Y Business Value (%)	Top Management support (%)	# Of dedicated resources (%)	Skills of the resources (%)	Extent of Use in PR & SM (%)	# of IT systems (%)	# of SM channels Presence (%)	Planning Culture (%)	Employee empowered Culture (%)	# internal social media (%)	IT-Security (%)	Access to own devices (%)	IT investment increase (%)	Providing employees devices (%)	Extent of Use in Innovation (%)	Business Value in PR & SM (%)		
0	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN		
10	5.6	NN	NN	NN	12.5	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN		
20	12.2	NN	NN	NN	12.5	NN	NN	NN	NN	NN	NN	NN	NN	NN	NN		
30	18.7	33.3	1.7	3.4	37.5	NN	NN	NN	NN	NN	NN	NN	NN	0.2	NN		
40	25.3	33.3	5.0	15.0	37.5	NN	NN	NN	NN	NN	NN	NN	NN	8.9	NN		
50	31.9	33.3	8.3	26.6	37.5	NN	0	NN	NN	NN	NN	NN	NN	17.5	NN		
60	38.5	33.3	11.7	38.1	40.0	NN	5.7	12.0	NN	NN	NN	NN	NN	26.1	NN		
70	45.0	33.3	15.0	49.7	37.5	NN	11.4	24.0	NN	8.6	NN	NN	NN	34.8	NN		
80	51.6	33.3	18.3	61.3	40.0	NN	17.1	36.0	NN	25.1	NN	NN	NN	43.4	NN		
90	58.2	33.3	21.7	72.8	40.0	NN	22.9	48.0	NN	41.6	NN	NN	NN	52.0	NN		
100	64.7	33.3	25.0	84.4	40.0	NN	28.6	60.0	NN	58.1	NN	NN	NN	60.7	NN		
Effect Size	0.319*** Large effect	0.250* Medium effect	0.094 Small Effect	0.308** Large effect	0.250* Medium effect	0.375** Large effect	0.071 Small Effect	0.150* Medium effect	0.036 Small Effect	0.169* Medium effect	0.223* Medium effect	0.063 Small Effect	0.288* Medium effect	0.209* Medium effect	0.278* Medium effect		
Ceiling Line	CR-FDH	CE-FDH	CR-FDH	CR-FDH	CE-FDH	CE-FDH	CR-FDH	CR-FDH	CE-FDH	CR-FDH	CR-FDH	CE-FDH	CR-FDH	CR-FDH	CR-FDH		

Ceiling lines for 13 of the 17 necessary conditions of which 9 have a significant effect. In addition to this, use of social media for promotion and selling leading to business benefits are two additional necessary conditions.

Paper III: A Set Theoretical Approach to Maturity Models: Guidelines and Demonstration

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A Set Theoretical Approach to Maturity Models: Guidelines and Demonstration

Completed Research Paper

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Abstract

Maturity Model research in IS has been criticized for the lack of theoretical grounding, methodological rigor, empirical validations, and ignorance of multiple and non-linear paths to maturity. To address these criticisms, this paper proposes a novel set-theoretical approach to maturity models characterized by equifinality, multiple conjunctural causation, and case diversity. We prescribe methodological guidelines consisting of a six-step procedure to systematically apply set theoretic methods to conceptualize, develop, and empirically derive maturity models and provide a demonstration of its application on a social media maturity data-set. Specifically, we employ Necessary Condition Analysis (NCA) to identify maturity stage boundaries as necessary conditions and Qualitative Comparative Analysis (QCA) to arrive at multiple configurations that can be equally effective in progressing to higher maturity.

Keywords: Maturity Model, Set Theory, Necessary Conditions, Sufficient Conditions, Necessary Condition Analysis (NCA), Qualitative Comparative Analysis (QCA).

III.1 Introduction

Maturity models in information systems (IS) academic research are understood as tools that can (a) aid the facilitation of internal and/or external benchmarking, (b) showcase possible process and outcome improvements, and (c) provide guidelines for the evolutionary process of organizational development and growth (Mettler et al. 2010). Maturity models in IS industry practice are normative and prescriptive by nature (Davenport and Harris 2007; Lahrmann et al. 2011; Nolan and Gibson 1974). However, developing a theoretically informed, methodologically rigorous, and empirical validated maturity model is subject to intense debate and fierce critique in IS research (Becker et al. 2010; King and Kraemer 1984a) and related disciplines (Andersen and Henriksen 2006; Kazanjian and Drazin 1989; Wendler 2012). Scholars have been debating back and forth on maturity models' design without really maturing on argumentation types, methodological techniques, or evidential grounds. In particular, the criticism that progression towards maturity does not necessarily occur through a linear sequence, but instead through configurations of multiple complex organizational and environmental conditions (Solli-Sæther and Gottschalk 2010) been left unaddressed.

In our quest to address this fundamental criticism with maturity models research, we drew from the recent developments in management science on the application of set-theoretic methods in typology and configurational research (Bedford et al. 2014; Fiss 2011). While a literature review on typology research is beyond the scope of this paper, after reviewing the relevant literature in management science (Bedford and Sandelin 2015; Doty et al. 1993; Fiss 2011; Miller 1996), we find two main similarities between maturity models and typologies in terms of underlying principles and problems encountered: (1) both maturity models and typologies allow users to cognitively simplify a complex environment by highlighting commonalities, allowing comparisons and providing holistic understanding, and (2) typologies move beyond traditional linear or interaction models of causality and maturity models also need to do so. While the lack of empirical research for conceptualizing and testing configurations is primarily attributed to lack of appropriate methods, the set-theoretic approach addressed these pressing concerns (Bedford et al. 2014; El Sawy et al. 2010; Fiss 2007; Fiss 2011). Given that maturity model research in IS faces isomorphic problems and challenges as typology research in management research, we employ the methodological advancements in set theoretic methods, specifically Qualitative Comparative Analysis (QCA) (Ragin 2008; Thiem and Dusa 2012; Wagemann and

Schneider 2010), and a novel method called Necessary Condition Analysis (NCA) (Dul 2016c) to address the following research question:

“How can maturity stages, boundary conditions and stage configurations be conceptualized by using set theoretical methods?”

The rest of the paper is organized as follows. First, we provide a brief exposition of the set-theoretical approach to social science in terms of its central attributes and advantages; review relevant literature on set theoretic methods in social sciences, especially QCA; and briefly discuss its advantages and recent advancements. We then present the NCA as a method that can complement QCA in identifying necessary conditions. Second, we discuss maturity models in IS research and define the core components that constitute a maturity model. We conceptualize maturity components in terms of necessary and sufficient conditions and present our research propositions. Third, we present guidelines consisting of a six-step procedure to derive a set-theoretic maturity model. Fourth, we demonstrate it on a social media maturity dataset. Fifth and last, we discuss our results, limitations and outline future research directions.

III.2 Set-Theoretical Social Science

Set theory constitutes the foundations of mathematics (Halmos 1960; Kechris and Kechris 1995) with direct applications to social science research (Ragin 2008). Set theoretical approach to social science (Ragin 2000; Ragin 1987; Schneider and Wagemann 2012) is characterized by three central attributes: *equifinality* (multiple pathways to the outcomes), *multiple conjunctural causation* (configurations of multiple causes rather than unicausal reduction), and *case diversity* (inclusive of both positive and negative outcome cases). Based on Smithson and Verkuilen (2006), Vatrapsu et.al (2014; Vatrapsu et al. 2016) have highlighted key advantages of applying classical set theory (Kechris and Kechris 1995) in general and fuzzy set theory (Zadeh 1965) in particular to social science research:

- (f) *Set-theoretical ontology* (e.g. Crisp Sets, Fuzzy Sets) is well suited to conceptualize vagueness, which is a central aspect of many social science constructs. For example, the concept of organizational maturity in is quite vague compared to the concept of maturity in biology.
- (g) *Set-theoretical epistemology* is well suited for analysis of social science constructs that are both categorical and dimensional. That is, set-theoretical approach is well suited for dealing with different degrees of a particular type on construct. For

example, the concept of organizational maturity like social science constructs such as culture, personality, and emotion is both categorical and dimensional.

- (h) *Set-theoretical methodology* can analyze multivariate associations beyond the conditional means and the general linear models which allows for both quantitative variable centered analytical methods as well as qualitative case study methods. In the case of maturity models, this allows for both variable centered analytical methods like surveys as well as qualitative case studies.
- (i) *Set-theoretical analysis* has high theoretical fidelity with most social science theories which are usually expressed logically in set-terms. For example, maturity model stages like theories on market segmentation and political preferences are logically articulated as categorical inclusions and exclusions that natively lend themselves into set theoretical formalization.
- (j) *Set-theoretical approach* systematically combines set-wise logical formulation of social science theories and empirical analysis using statistical models for continuous variables. For example, in the case of maturity models, it is possible to employ crisp set and fuzzy set theory to dynamically derive data points for maturity variables.

Given the above advantages, applications of set theory are not new to social science research; however, its application to management science and IS research has been very recent. Apart from use of Venn diagrams to visualize big social data (Jussila et al. 2016; Vatrapu et al. 2015), formalized applications of set theory in IS research are mainly attributed to the method of “Qualitative Comparative Analysis (QCA)” developed by (Ragin 1987). Examples of application of QCA include; (i) use of fsQCA to develop and test typologies in management sciences (Bedford and Sandelin 2015; Fiss 2007); (ii) investigation of user resistance to IT (Rivard and Lapointe 2012) and electronic service failures (Tan et al. 2016) in IS. Although developed initially by Ragin (1987) for qualitative case study researchers (medium sample size of $N < 90$), the proponents of QCA have since then argued about its unique advantages over regression-based approaches (Cooper 2005; Emmenegger et al. 2014; Wagemann and Schneider 2010) and its application for analysis of large-N datasets (Cooper 2005; Emmenegger et al. 2014). In the increasing adoption trajectory of QCA in social sciences (Thiem and Dusa 2012), three variants have surfaced: (a) crisp-set QCA (CsQCA), (b) fuzzy-set QCA (fsQCA) (Ragin 2008), and (c) multi-value QCA (MvQCA) (Wagemann and Schneider 2010), with a number of software tools

supporting set-theoretical social science researchers (e.g. fs/QCA, Tosmana , R packages like QCA and QCAPro).

III.2.1 Qualitative Comparative Analysis (QCA)

QCA is a set-theoretical method that models causal relations as subset or superset relations in terms of necessity and sufficiency. QCA focusses on arriving at casually complex patterns in terms of equifinality, multiple conjunctural causation and asymmetry (Fiss 2007; Ragin 1987; Ragin 2008; Wagemann and Schneider 2010). QCA is designed to compare multiple cases in terms of complex configurations of conditions and outcomes (Bedford and Sandelin 2015). The ultimate goal of QCA is to *analyze set-theoretic sufficiency relations* (Ragin 1987). QCA is grounded in the analysis of set relations, not correlations (Ragin 2006; Ragin 2008) and hence unlike conventional statistical methods it does not measure the average effect of an increase or decrease of one variable on another. Instead, QCA analyses complex connections between attributes and outcomes in terms of set relationships (Bedford and Sandelin 2015). As such, identifying the necessary and sufficient conditions form the core of any set-theoretic approach. In their simplest form, either Euler/Venn diagrams or cross-tabulation techniques are used or in the case of continuous membership scores (fuzzy set), the X-Y plot is adopted (Goertz 2006; Mahoney and Vanderpoel 2015; Wagemann and Schneider 2010). Figure 1 illustrates the core analytical logic of set-theoretical approach in general and QCA in particular.

First, let's look at "*necessary conditions*", as without them the outcomes cannot occur, and other conditions cannot compensate for their absence (Dul 2016c; Goertz 2006; Ragin 2008), "X is a necessary condition of Y, if Y cannot happen without X". A necessary condition, therefore is an antecedent condition that is a superset of the outcome (Mohr 1982; Ragin 2008). As shown in Figure 1, one could detect a necessary condition, just by inspecting the Euler/Venn diagram or the X-Y plot. With both crisp and fuzzy sets (Figure 1: 1st and 3rd column - 1st row), the necessary condition is represented as a superset relation and indicated as $X_i \geq Y_i$ (X is a superset of Y). Another way of identifying necessary conditions is using cross-tabulation (lower left corner of Figure 1). A test for necessity essentially requires us to look at only the first row (cells 1 & 2), while cells 3 and 4 are completely irrelevant. The test for sufficiency however proceeds from the *observation of some condition(s) X to the observation of the outcome Y* (Thiem and Dusa 2012; Wagemann and Schneider 2010) as illustrated in Table 1, i.e. "X is a sufficient condition of Y, if X implies Y or X is a subset of Y".

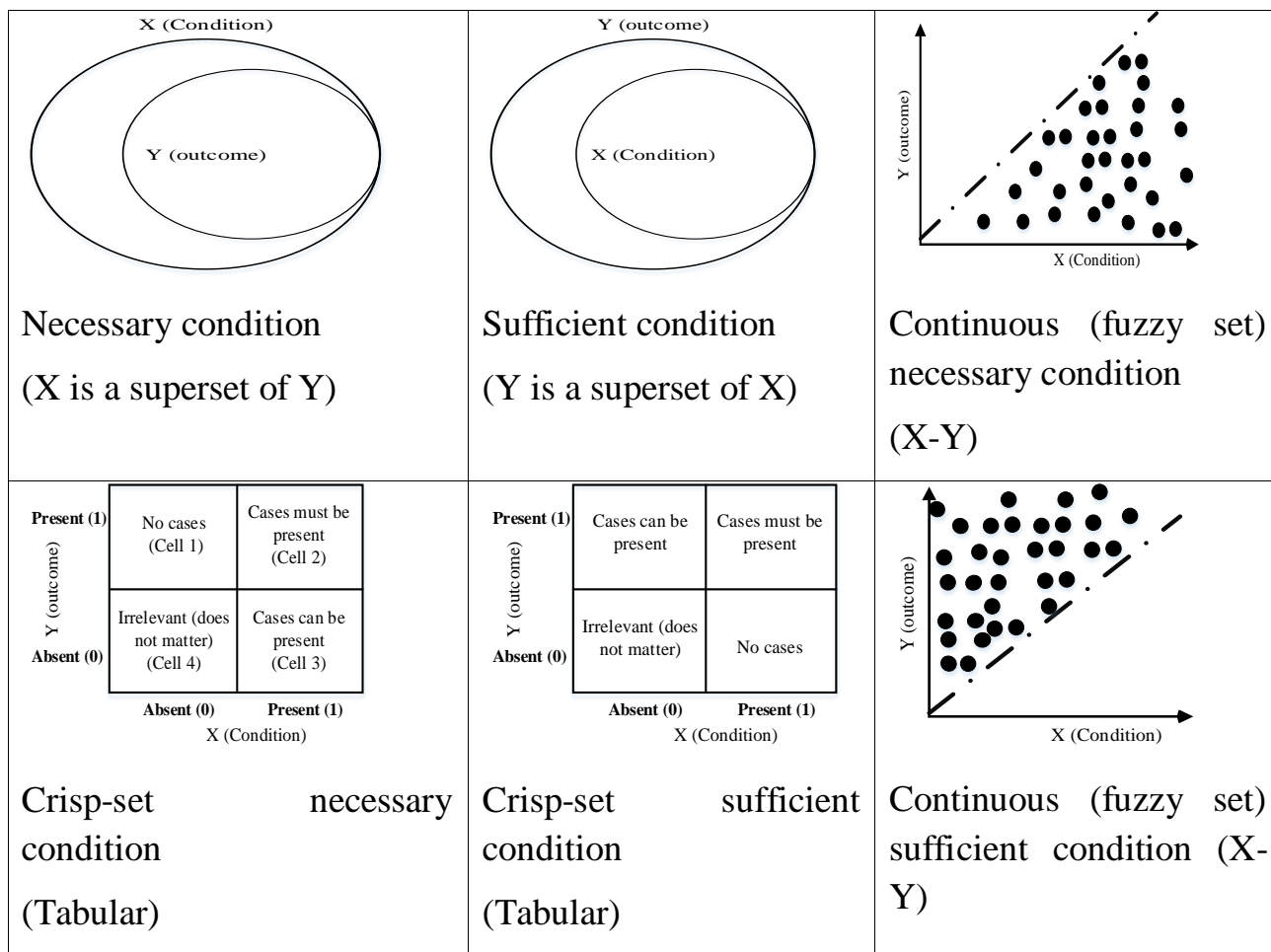


Figure 1: Necessary and Sufficient Conditions.

While the method of single condition analysis (Figure 1) is of analytical value, according to Ragin (2006), examining relations between binary variables “*might be considered adequate as a descriptive starting point, but this approach is too crude to be considered real social science*’. Moreover, social sciences in general (Mohr 1982) and information systems in particular deal with what are INUS conditions: *insufficient but non-redundant part of an unnecessary but sufficient condition* (Ortiz de Guinea 2014). QCA scholars have argued the advantages of set-theoretical methods in explaining INUS conditions and developed a number of measures (Goertz 2006; Ragin 2006) and guidelines (Wagemann and Schneider 2010) to make analysis of complex causations possible. These include guidelines to develop a truth table, calibration of original data to sets, measures of *consistency*, *coverage* (Ragin 2006), and also some diagnostics to detect logical contradictions and paradoxical relations (Bedford and Sandelin 2015; Thiem and Dusa 2012). QCA uses crisp and fuzzy set algorithm (Quine-McCluskey) combined with qualitative counterfactual analysis to arrive at the final Boolean solution i.e. intermediate solution (Ragin 2008; Thiem and Dusa 2012;

Wagemann and Schneider 2010). While the detailed discussion explaining the purpose of each of these measures is not warranted within this paper’s scope, we discuss the steps of applying QCA in the forthcoming demonstration section.

III.2.2 Necessary Condition Analysis (NCA)

“NCA⁵⁶” is a technique for identifying *relationships of necessity that can make both statements in kind and in degree* (Dul 2016a). NCA uses *Data Envelopment Analysis* (DEA) based techniques. While QCA as set-theoretic method has a number of advantages in the analysis of complex causations, some scholars (Goertz 2006; Vis and Dul 2016) argue that in few cases QCA fails in identifying all necessary conditions, specially single necessary conditions. Vis and Dul (2016) argue that calibration of original data into set-memberships leads to non-detection of some necessary conditions. In order to address this problem, NCA (Dul 2016c) is proposed as a method for identifying necessary conditions in data sets, be they categorical or dimensional in nature. A comparison of NCA and QCA (table 1) highlights NCA’s advantage in identifying more single necessary conditions, and calculating the level of the condition that is necessary for the outcome.

Table 1: Comparison of NCA and QCA (Vis and Dul 2016)

Characteristic	QCA	NCA
Underlying logic	Configurations are sufficient but not necessary to produce the outcome (“equifinality”)	Single conditions are necessary but not sufficient to allow the outcome
Measures to detect presence of “in kind” necessary condition(s).	Necessity Consistency >0.9	Effect Size “d” >0.1
Formulation of an “in degree” necessary hypothesis	Not Applicable (NA)	“Level X is necessary for Level Y” (Ceiling line)
Identification focus	Sufficient but not	Single Necessary conditions

⁵⁶ Steps to perform NCA has been discussed and demonstrated on page 8, 9 and 12 in this paper.

	necessary configurations and Necessary “OR” Configurations	
Analytic approach	Boolean Algebra (Set theory)	Ceiling line (Data envelopment analysis)

After reviewing of literature on QCA and NCA, it is clear that while QCA works on configurational logic and assumptions of equifinality, NCA focusses primarily on single conditions. We concur with Vis and Dul (2016) that NCA can compliment QCA and apply both these techniques to empirically derive a maturity model, while addressing the criticisms pertaining to multiple paths to maturity.

III.3 Set Theoretical Approach to Maturity Models

In this section, we present the formulation of maturity model components as necessary and sufficient conditions. First, we briefly discuss the core components of maturity models, current criticisms and then state our propositions to address these criticisms.

III.3.1 Concept and Core Components of a Maturity Model

In IS research, the purpose of maturity models is to outline the path to organizational maturation with regard to a business technology and/or process, including defining the stages and relationship between them (Pöppelbuß et al. 2011). We analyzed a number of maturity models (Damsgaard and Scheepers 1999; Duane and OReilly 2012; Joachim et al. 2011; Nolan and Gibson 1974; Paulk et al. 1993; Van Steenberg et al. 2013). We found that they can be classified into three broad types of stage fixed, stage continuous and focus area models, and that the underlying core components constituting a maturity model can be characterized in terms of: (1) Maturity Stage, (2) Conditions, (3) Boundary conditions, and finally (4) Path to maturity as illustrated in Figure 2.

Maturity Stage [Stage1... Stage n]: “Level” and “Maturity Score” are some of the other terms used. Stages typically are archetypal states of maturity of the entity that is being assessed. Each stage has a set of distinct characteristics that are testable (Nolan and Gibson 1974; Raber et al. 2012).

Conditions (X_{mn} , m factors and n stages): “Critical Success Factors”, “Dimensions”, “Factors”, “Enablers” “Benchmark Variables” and “Capabilities”

are some of the other terms. Conditions describe multi-dimensional factors that decide the entity's maturity stage. Each condition is also further classified into a number of sub-factors with specific characteristics at each stage (Raber et al. 2012).

Boundary Conditions [B1... Bn]: Also termed "Triggers", "Dominant Problems" (Solli-Sæther and Gottschalk 2010) and "Inhibitors", boundary conditions are specific conditions that the entity has to satisfy in order to progress from one stage to another (Lasrado et al. 2015).

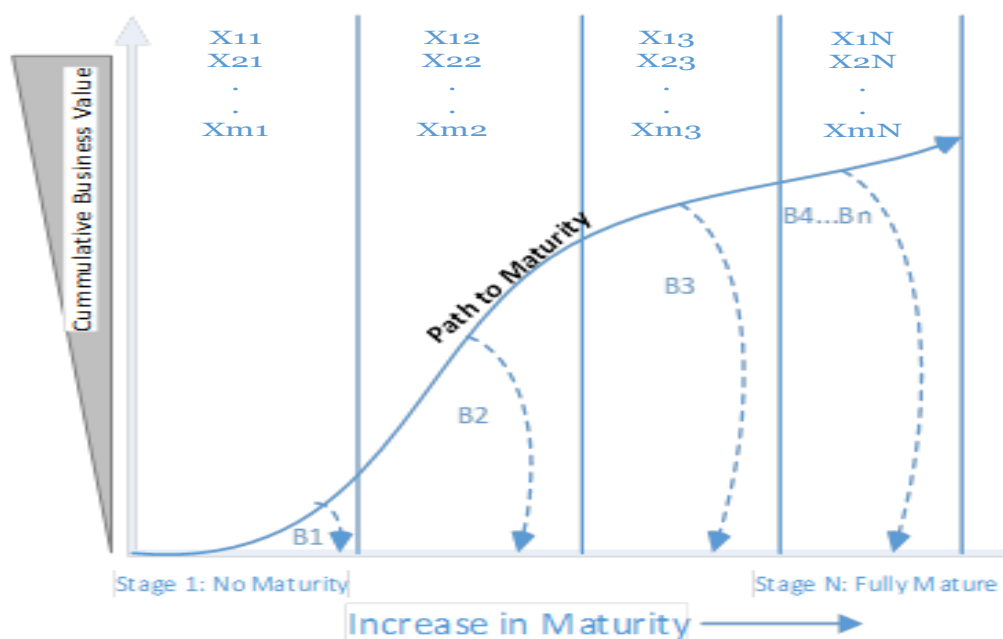


Figure 2: Core Components of a Maturity Model (Lasrado et al. 2016).

With regard to the criticism of maturity models in IS, some researchers (King and Kraemer 1984a; Solli-Sæther and Gottschalk 2010) have questioned the very concept of stages of growth while others have criticised the lack of theoretical foundations and accusing researchers of blindly adopting influential models such as the Capability Maturity Model (CMM) for their structure and not conceptually grounding the maturity model characteristics in theory (Pöppelbuß et al. 2011; Renken 2004). Moreover, the lack of empirical validation in the selection of variables (Lahrman et al. 2011; Wendler 2012), and rarity in use of empirical (i.e. qualitative, quantitative) or other demonstration methods (Lasrado et al. 2015; Wendler 2012) have also been widely critiqued. While most of the research related to maturity models has been largely conceptual (Pöppelbuß et al. 2011), very few maturity models (Damsgaard and Scheepers 1999; Raber et al. 2012) have acknowledged and attempted to address these

criticisms. Finally, the underlying assumption of a single linear path towards maturation with no possibility of equifinality has been widely critiqued (King and Kraemer 1984b; Lasrado et al. 2015; Solli-Sæther and Gottschalk 2010). Overall, the fundamental criticism of maturity models research in IS can be summarised as follows:

“IS literature has mostly ignored theoretical approaches to maturation – the process of becoming more mature has been understood rather vaguely.... Maturity models in IS research requires conceptualizations and analytical perspectives better grounded in theory” (Becker et al. 2010)

III.3.2 Mapping Maturity Stages and Stage Characteristics to Set Theoretical Concepts

From the definition stated in Figure 2, it is evident that without satisfying the boundary conditions criteria, an entity cannot progress from a state of low maturity to high maturity further irrespective of satisfying all other conditions. For example, in the case of Intranet Maturity Model (Damsgaard and Scheepers 1999), every stage has a boundary condition. While active support of a technology champion is a boundary condition to progress from stage 1 to stage 2, critical mass of intranet users is a boundary condition to progress to stage 3. Similarly, in the case of Analytics Maturity (Davenport and Harris 2007), an enterprise wide implementation is required to progress from stage 3 to stage 4. Hence, active support of a technology champion, critical mass of intranet users, and enterprise wide implementation are compulsory pre-conditions for increase in maturity. By definition, such pre-conditions are known as “necessary conditions” (Dul 2016c). In other words, the absence of these necessary conditions guarantees failure in terms of progression to the next stage of the maturity model. Moreover, if both the maturity (Y) and conditions (X) causing it can be quantitatively measured, then the level of condition (X) necessary to cause certain level of maturity (Y) can be established using Necessary Condition Analysis (NCA). In line with the above two arguments, we state our first two propositions:

P1a: Boundary conditions are necessary conditions.

P1b: Necessary Condition Analysis (NCA) would facilitate formulation of maturity stage boundaries by calculating the level of boundary conditions necessary for the level of maturity required.

Furthermore, although scholars agree that maturation means path to something better and advanced, many scholars (Becker et al. 2010; Kazanjian and Drazin 1989; King

and Teo 1997) have contested the assumption that the path to maturity is linear. We agree that this linear path of progression posited excludes the possibility of equifinality. We further concur with Kazanjian and Drazin (1989) and (Solli-Sæther and Gottschalk 2010) that progression towards maturity does not necessarily occur through a linear sequence of stages and we argue that maturity progression occurs through configurations of multiple complex conditions. Drawing from recent set-theoretical research through application of QCA (El Sawy et al. 2010; Fiss 2011), we propose the configurational approach for deriving multiple paths to maturity. In other words, we adopt the notion of “equifinality” that an entity or system can *reach the same outcome from different initial conditions and through many different paths* (El Sawy et al. 2010) and list our final proposition:

P2: Qualitative Comparative Analysis (QCA) would yield multiple configurations for an entity to be in a particular maturity stage.

In the next section, we present guidelines for set-theoretical maturity models consisting of a six-step procedure and empirically demonstrate the set-theoretical approach stated above using a real-world dataset.

III.4 Set Theoretical Maturity Models: A Six-Step Procedure

In this section we propose a six-step procedure (see figure 3), the elements of which are informed by (a) detailed review of guidelines and procedures for developing maturity models (Becker et al. 2011; Mettler et al. 2010; Solli-Sæther and Gottschalk 2010), (b) guidelines for standard practices in QCA (Fiss 2011; Goertz 2006; Thiem and Dusa 2012; Wagemann and Schneider 2010), and (c) guidelines for NCA (Dul 2016a; Vis and Dul 2016). The six-steps are represented in the form of a flow chart, with explanations of the notation used given at bottom-right of the figure 3.

Step 1: The first step starts with *problem definition* (1a & 1b). Step 1a calls for a detailed description of maturity model that includes its scope, targeted audience and main stakeholders involved (Mettler et al. 2010). The purpose of this step is to facilitate comparison with similar maturity models and check for practical relevance. Further, it is important to formulate maturity, while emphasizing what conditions (X), both individually or in combination need to be in place (i.e. necessary conditions) and what conditions (X), both individually or in combination would produce maturity (i.e. sufficient conditions). Therefore, step 1a also requires developing and describing a conceptual model together with detailed description of conditions (X), the

measurement of maturity or its proxy (Y) and the direction of causality. This step also guides and informs the case selection (step 1b). While random sampling should suffice for NCA, purposeful case selection is a crucial step for QCA as it seeks to identify both necessary and sufficient conditions (Kane et al. 2014; Ragin 2008). Step 1b requires the researcher to include cases that both exhibit and do not exhibit the outcome of maturity. The purpose of this case diversity is to ensure that the analysis leads to multiple configurations or pathways to maturity. A thorough understanding of the conditions and cases in question must be achieved and documented well before proceeding to analysis phase (step 2).

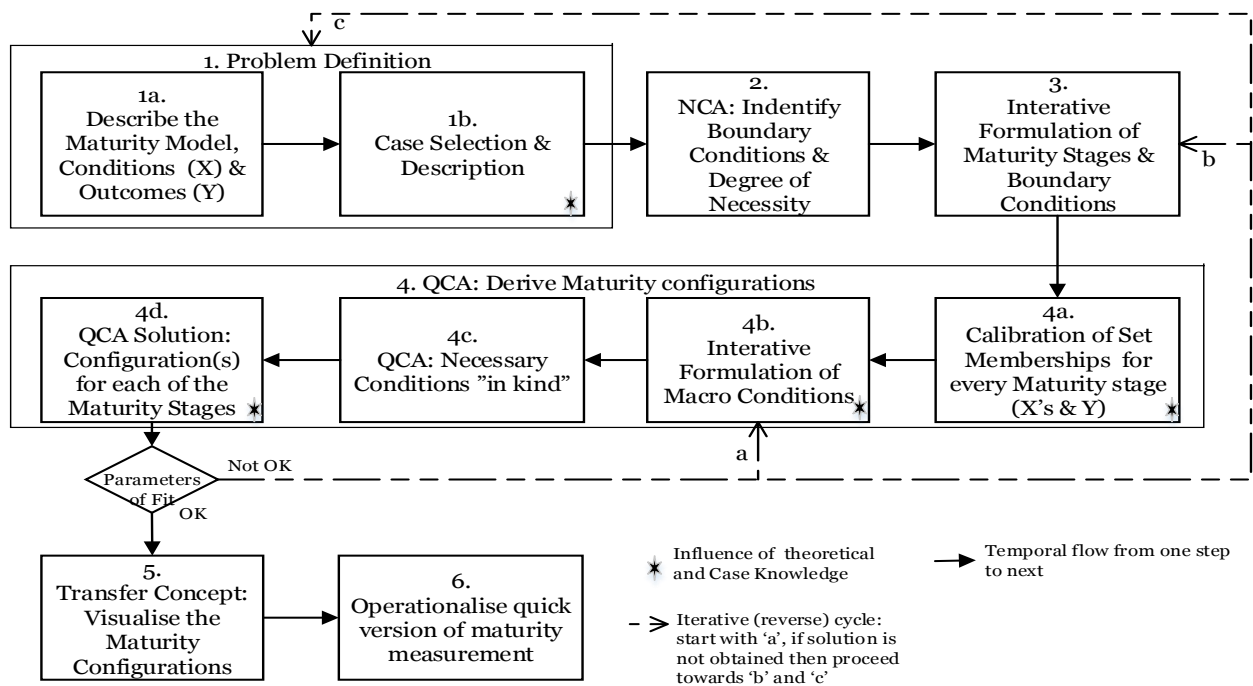


Figure 3: A Six-Step Procedure for Set Theoretical Maturity Models.

Step 2: This step requires performing NCA on the original dataset, examining the NCA graphs (X-Y plots) and evaluating the effect size. Following proposition 1a and 1b, the purpose of NCA is to identify stage boundary conditions and the level necessary for maturity. In NCA this is done by calculating the area of emptiness in the top right corner of the X-Y plot as illustrated in Figure 4. To draw ceiling lines, various techniques are prescribed in the R package (Dul 2016b) for NCA. Depending on how the condition is measured (i.e. discrete or continuous) and the interpretability of the results, the appropriate type of ceiling line (i.e. CE-FDH, CR-FDH or any other) is

selected⁵⁷. The necessary condition effect size ranges from 0 to 1 and Dul (2016c) suggests to use effect size of 0.1 as the threshold as “any necessary condition hypothesis in the continuous case (X is necessary for Y) is rejected if the effect size d is less than 0.1” (Dul 2016a; Dul 2016c). Finally, the level of conditions (X) that are necessary are listed against the outcome (i.e. level of maturity) as shown in Figure 4 and reflected upon in a tabular format⁵⁸ as this step informs formulating maturity stage boundaries (step 3) and also influences calibration (step 4a).

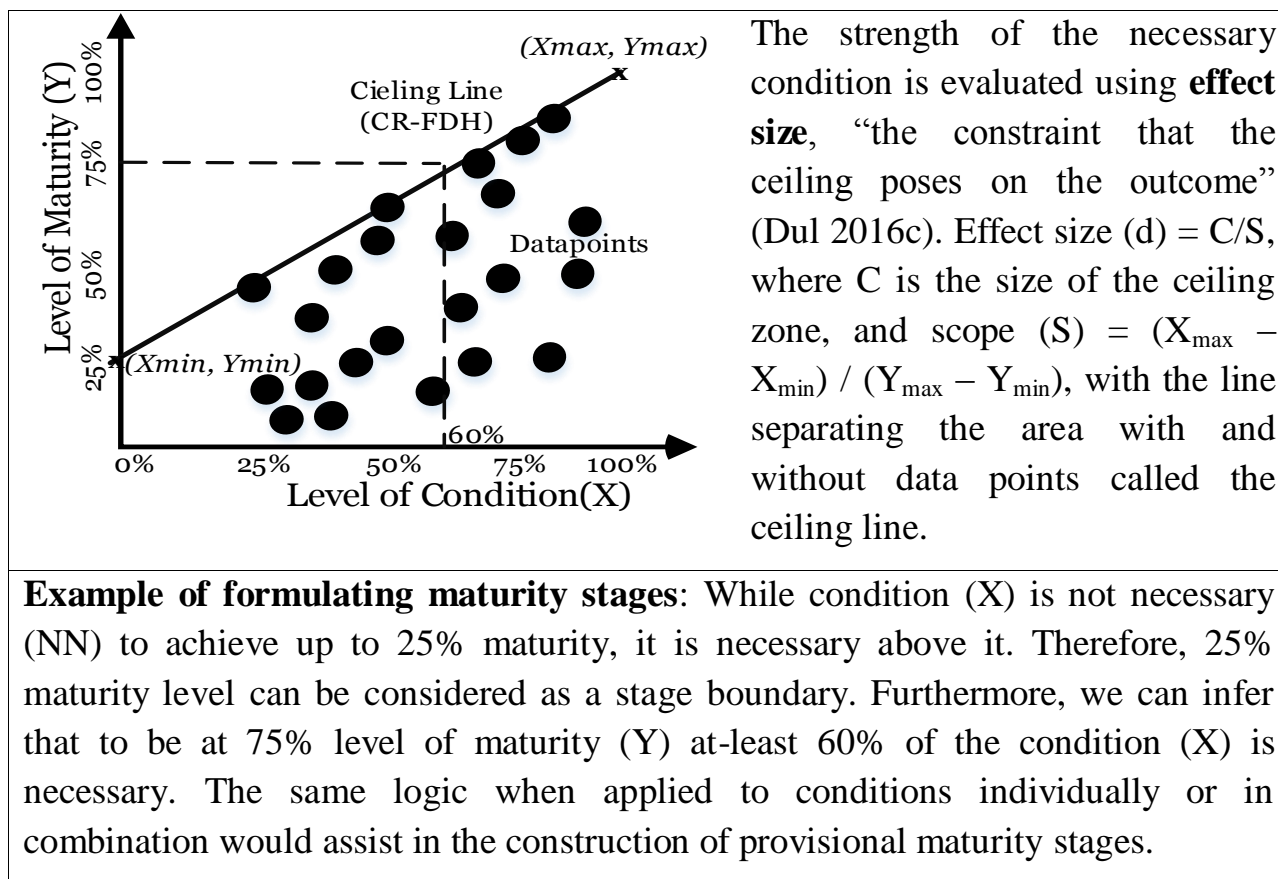


Figure 4: Necessary Condition Analysis & Maturity Stages.

Step 3: *Formulation of maturity stages, boundary conditions* for those maturity stages form the central phase of the six-step procedure. As illustrated in Figure 3, step 3 is iterative, wherein the number of maturity stages and stage boundaries are arrived at through while traversing between theoretical ideas from prior maturity model literature, empirical results from the NCA bottleneck table and from QCA (step 5) up until the parameters of fit² are satisfied. In the first iteration, in line with prior maturity

⁵⁷ A piecewise linear ceiling with free disposal hull technique (CE-FDH) and a ceiling regression with free disposal hull technique (CR-FDH) is suggested for discrete and continuous data respectively as “they produce stable results with relatively large ceiling zones” (Dul 2016c).

⁵⁸ The tabular format is referred to as the bottleneck table (Dul 2016c).

model design practices (Karkkainen et al. 2011; Lahrman et al. 2011; Lasrado et al. 2015; Raber et al. 2012), the first strategy is to select the number of stages as 4 or 5 and draw the stage boundaries by evenly dividing the maturity measure (Y). For example, if the maturity is measured using a 5 point Likert scale (0-5) and the number stages are 5; the stage boundaries are drawn at equal intervals (0, 1, 2, 3, and 4). The second strategy is to use the NCA results to propose stage boundaries (Lasrado et al. 2016) as illustrated in figure 4. The third strategy is to follow the configurational approach (El Sawy et al. 2010; Fiss 2011) and draw the maturity boundaries against a benchmark; choice of the benchmark must be supported by strong theoretical arguments or empirical evidence. The execution of the third strategy is in tandem with calibration of set memberships (4a). Using one or a combination of the three strategies listed above, the first provisional maturity stages and their respective boundaries are drawn.

Step 4: The purpose of this step is to facilitate the extraction of configurations for maturity stages using QCA. QCA is a well-established method with prescribed guidelines³ that involves calibration of data into set memberships, formulating the truth table, Boolean minimization, counterfactual analysis, and finally arriving at the most parsimonious and intermediate solutions. Calibration of set memberships (4a) is a crucial step in QCA requiring the researcher to assign set membership scores to both outcome (Y) and conditions (X). Here the researcher needs to establish qualitative crossover points (Fiss 2011; Ragin 2008) to assign membership to particular sets. Calibration⁵⁹ is done either by direct or transformational assignment (Ragin 2008). While a taxonomy of calibration scenarios have been proposed in the literature (Thiem and Dusa 2012), QCA scholars (Wagemann and Schneider 2010) state that it is the responsibility of the researcher to find valid reasons to assign these set membership scores. Following the calibration of the outcome (i.e. maturity), the conditions (X) are also calibrated into set memberships and macro conditions³ are formulated (4b). The next step (4c) involves testing for necessity again using QCA. The purpose of step 4c is to (i) validate the single necessary conditions identified via NCA and, (ii) check if the necessary conditions identified are valid even after the maturity stage boundaries

⁵⁹ Given the page constraints of this paper we are unable to include detailed steps on how to perform QCA including calibration. Readers are referred to the next section wherein calibration, creating macro conditions and application of QCA is demonstrated using a social media maturity dataset; especially reasons for formulating macro conditions are discussed in detail. Furthermore, in order to understand the philosophy of QCA, readers are referred to Ragin (2008). For a detailed description of the steps and the guidelines to perform QCA, readers are referred to Wagemann and Schneider (2010) and Thiem and Dusa (2012). Finally for application of QCA in configurational research, we refer the readers to Fiss (2011) and Bedford and Sandelin (2015). Parameters of fit are prescribed tests to approve the final QCA solution. Readers are referred to Thiem and Dusa (2012) for prescribed tests and formulae (page 69-73).

are drawn. Prior research on NCA and QCA (Vis and Dul 2016), highlight the fact that NCA identifies more necessary conditions than QCA; if this fact is proved it is required to revisit the calibration logic and document the impact of calibration on the results. QCA works in an iterative cycle until an optimal solution is obtained in what Ragin (2008) terms as an “analytical moment”. This iterative cycle leads to formulations of new macro conditions, new maturity stage boundaries and improved case knowledge as illustrated in figure 3.

Step 5: The fifth step called *transfer concept* provides visualization of maturity configurations in a format that is easily understood by the target audience. There are multiple options suggested in literature to present the results [e.g. Core-Periphery Configuration Chart (Fiss 2011), Solution as Boolean Expression (Ragin 2008; Thiem and Dusa 2012), Relevance-Trivialness Table (Goertz 2006)]. Since the audience for maturity models is usually management oriented, we recommend the Core-Periphery Configuration Chart, given its visual symmetry with prior maturity models and ease of understanding for non-experts who are not familiar with Boolean expressions.

Step 6: Last but not the least; we propose to create and *operationalize a condensed version of maturity measurement* to serve as a quick diagnostic tool. In order to do so, it is very important to clearly understand the requirements of the main stakeholders (De Bruin et al. 2005). Apart from direct communication with the main stakeholders, a review of existing maturity measurement instruments must be performed before developing the quick diagnostic tool.

III.5 Demonstrative Case Study: Social Media Maturity Model

This section demonstrates the application of the six step procedure on a real-world dataset to derive a Social Media Maturity Model. Although, both QCA (Ragin 2008) and NCA (Dul 2016c) are advocated as research approaches as well as data analysis techniques, in this section, we demonstrate primarily their data analysis capabilities in line with the six-step procedure outlined in the previous section.

Step 1: Maturity Model & Case Description, Conditions (X's) and Outcome (Y)

The main stakeholder for social media maturity model is the consortium of IT consultants and Danish organizations led by Networked Business Initiative (<http://www.networkedbusiness.org/>). NBI measured digital maturity of organizations with regard to five digital technologies and six business functions. The dataset used in this demonstration comes from a survey of 231 organizations. The targeted audiences

are managers (top and middle management) in Danish SME(s) interested in comparing their digital performance against peers. For the purpose of this demonstration, we limit our scope to customer facing activities (i.e. Sales & Marketing, and PR) and use a sample of 85 organizations (Table 2) that responded to a survey on social media maturity (details on items, scales, and definitions are provided in Table 3).

Table 2. Overview of Companies in the Demonstration Dataset.

Size/founded	2000 to 2008	After 2008	Before 2000	Grand Total	Domain	N
50 to 250	2	2	22	26	B2C	15
15 to 49	8	1	7	16	B2B	45
Less than 15	14	19	10	43	Both B2B & B2C	24
Grand Total	24	22	39	85	Others	1

The data is collected through a cross-sectional survey linked to a live dashboard whose primary purpose is comparative benchmarking of participating organizations in Denmark. Given the space constraints and the demonstrative purposes of the dataset, we do not discuss the survey design, administration and data collection aspects in detail. The social media maturity dataset consists of 14 conditions (X's) and one outcome (Y) as listed in Table 3. We use Business value realized in PR and Sales & Marketing as the outcome (Y). The rationale behind this is based on our first assumption about maturity: “*Maturation means the path to something better*”, which translated to our demonstrative case is “**social media maturity \propto business value**”. We thus infer that higher the social media maturity of an organization, better or higher business value is realized. Thus, we employ business value realized in PR, Sales & Marketing (Y) as a proxy measure for the maturity.

Table 3. Overview of Conditions.

Condition (X)			Scale; # of items
Management	Top Management encourages the use of social media throughout the organization.	MUS	Likert (0-4); 1
	IT investment within the organization as compared to previous years, understanding the intention of	INV	Ordinal scale (0=decreased, 1=Sa

	management towards digitalization.		me, 2=increased); 1
	Digital strategy Index ⁶⁰	DS	Index (0 to 4); 1
IT Policy	Allowing access to Own Devices (OD) measured on access to number of systems, and/or Providing Employees With Devices (PEWD) measured on number of employees, while having a high IT Security Index ¹ (ITS) is considered as an organization with high social media maturity.	ITS	Index (scaled to 4); 1
		OD	Likert Scale (0-4); 1
		PEDW	Likert Scale (0-4); 1
Technology	Social media presence, measured as the number of social media channels.	ESC	Count (0 -8); 1
	Extent of Use of social media, measured as an average of PR and Sales & Marketing	U	Likert Scale (0-4); 2
	Number of resources (FTE) hired specifically for social media activities, measured as none, part time, full time and more than one. Sometimes, in case of SME's, a marketing manager or any other employee manages social media. Hence NBI also measured professional skills (S) available inside the organization that can manage social media.	FTE	Ordinal (0,1,2,3); 1
		S	Likert Scale (0-4) i.e. Not at all to Very high degree; 1
Metrics (M) is a measure of formalized social media activities. It is measured through the presence of either KPI's, workflows or both.	M	Ordinal (0,0.5,1); 2	
Culture	The measures for Culture are based on an organization orientation towards employee driven style of working and decision making (EEC), a well-planned and structured style (PSC), and an explorative culture wherein new IT systems are	EEC	Likert Scale (-2 to 2); 4
		PSC	Likert Scale (-2 to 2); 2

⁶⁰ The criterion for this index is the presence or absence of an overall digital strategy (measured as Yes/No), the extent to which this policy has been aligned with the company strategy, communicated and implemented across the company (measured using a 5-point Likert scale from 0 to 4). For example, if Organization A has no digital strategy (X1=0) then the index is calibrated as 0.0. However, if Organization B has digital strategy (X1=1), is aligned fully (X2=4), communicated largely (X3=4) and implemented to a small degree (X4=2). Then the digital strategy index for organization B is $(X1+X2+X3+X4)*4/13 = 3.384$, wherein 4 is calibration range and 13 is actual scale range. IT Security Index is also calculated in the same manner.

	always sought after. These are based on a factor analysis of seven items measured on 5-point scale i.e. Completely disagree (-2) to Completely agree (2).	NSC	Likert Scale (-2 to 2); 1
Y	Business Value from social media in customer facing activities measured as an average of PR and Sales & Marketing	BV	Likert Scale (0-4); 2

Step 2: Identify Boundary Conditions using NCA

Now that the conditions (X) and outcome (Y) are established, we apply NCA to identify the single necessary conditions. Following the steps proposed in the six-step procedure, 6 necessary conditions are identified as highlighted in figure 5. While the extent of social media use (U) has a large effect and can be determined as the most important necessary condition, rests of the 5 necessary conditions have a medium effect on maturity. As proposed in the six-step procedure, we use CE-FDH whenever the condition is discrete while CR-FDH is used when the condition is continuous in nature. In this demonstrative case, we use CE-FDH, for conditions INV and FTE. Using CE-FDH, we infer that hiring a part time resource (FTE) to work on social media is a necessary condition for delivering greater than 70% of the business value. CR-FDH in this case would make no sense as one cannot hire 20% of a part time resource. Furthermore, using the X-Y plot logic we also find that FTE is both necessary and sufficient as illustrated in figure 5. By definition, a sufficient condition “ensures the existence of the outcome (i.e., if X=1 then Y=1). But the outcome can also exist without the sufficient condition (i.e., if X=0, Y can still be 1)” unlike a necessary condition (Ragin 2008). In our case, we thus interpret that at least a part time FTE to handle social media operations is both necessary and sufficient, thus making it the most important condition to achieve high maturity.

Now that the “6 necessary conditions and their level necessary for maturity” are identified using NCA, the next logical step is to reflect and validate the necessary conditions. In this process of reflection, we observe that one necessary condition (EEC) is measured on a 5-point scale using values “-2 to 2” (completely disagree to completely agree); indicating any value less than “0” means that employee empowered culture (EEC) is actually not present. A value of “0” means at least 50% in the bottleneck table in figure 3. However, our results indicate that even to achieve 100% business value (Y), only 44.9% of EEC is necessary, which is less than 50% (required in this specific case) providing us strong empirical reasons to drop employee driven

culture (EEC) as a necessary condition although it has an effect size of 0.115. Therefore, we can conclude that that presence of EEC is not necessary for high or very high business value (Y)⁶¹. Similarly, both top management encouragement for use of social media (MUS) and investment in IT (INV) are not necessary (NN) to achieve up to 60% and 70% of business value (Y) respectively⁵. Therefore, in the next step if the high maturity stage boundary is drawn at 50% of business value (Y), then by definition MUS and INV will not be stage boundary conditions to be in high maturity. In addition to the above reflections, this necessity validation happens iteratively and in tandem with the next 2 steps.

	BV (%)	MUS	FTE	Skills	USE	ESC	EEC	PSC	INV
Low	0	NN	NN	NN	NN	NN	NN	NN	NN
	10	NN	NN	NN	NN	12.5	NN	NN	NN
	20	NN	NN	NN	4.7	12.5	NN	NN	NN
	30	NN	NN	NN	14.2	12.5	NN	NN	NN
	40	NN	NN	NN	23.8	12.5	NN	NN	NN
High	50	NN	NN	NN	33.4	12.5	0.9	NN	NN
	60	NN	NN	NN	43.0	12.5	9.7	5.7	NN
	70	12.8	33.3	5.0	52.6	12.5	18.5	11.4	NN
	80	26.1	33.3	11.7	62.2	12.5	27.3	17.1	50.0
Very High	90	39.4	33.3	18.3	71.8	25.0	36.1	22.9	50.0
	100	52.8	33.3	25.0	81.3	25.0	44.9	28.6	50.0
MATURIT Y-^	Effect Size	0.104*	0.125*	0.047	0.402**	0.141*	0.115*	0.071	0.125*
	Effect	Mediu m	Mediu m	Small	Large	Mediu m	Mediu m	Small	Mediu m
	Ceiling Line	CR- FDH	CE- FDH	CR- FDH	CR- FDH	CE- FDH	CR- FDH	CR- FDH	CE- FDH

⁶¹ QCA necessity test (Consistency = 0.92, coverage = 0.5) validates the claim that presence of EEC, MUS and INV a not necessary for high maturity stage. Moreover EEC is part of an INUS condition (configuration P2a). Similarly MUS and INV are part of configuration P2b and P2c, but not P2a.

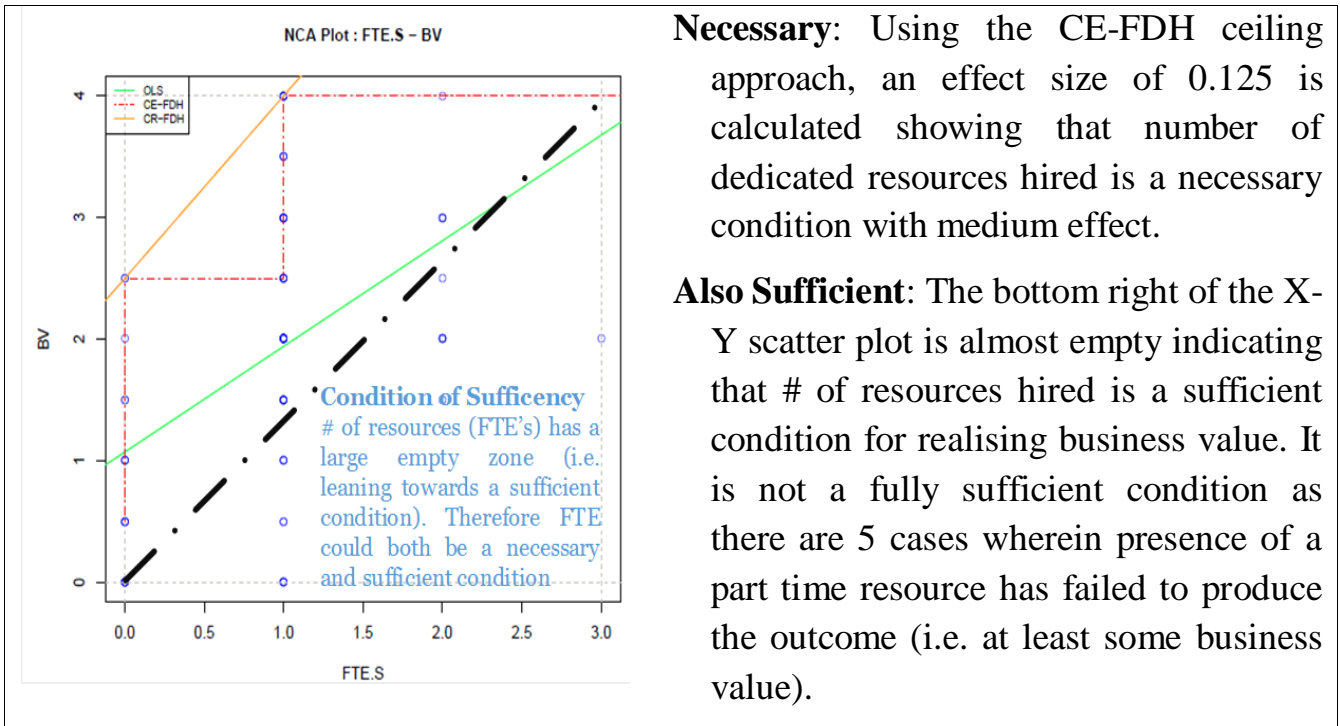


Figure 5: X-Y Plot, Ceiling Zone, Effect Size and Bottleneck Table.

Step 3 & 4a: Formulation of Maturity Stages, Boundary Conditions and Calibration

As shown in figure 3, step 3 is part of an iterative cycle and can also be performed in tandem with calibration set memberships for QCA. Following the recommendations from procedure model, we adopt a combination of second (NCA bottleneck table), and third strategy (benchmarking) to propose maturity stages. While in our first iteration we propose 4 maturity stages (No, Low, High, Very High), after two iterations we end up with 3 maturity stages as illustrated in Figure 5.

Moreover, our primary interest in this step is in defining the social media maturity stages in terms of set memberships, which we have measured through a proxy of business value realized (Y). It is measured using a Likert scale (interval of 0 – 4) for PR and Sales & Marketing respectively, which we then average to get a score between 0 – 4. First, following the configurational approach (El Sawy et al. 2010; Fiss 2011), we also create two fuzzy set measures of above-average business value realized (i.e. set with high maturity). This “benchmark” of average is set at 50% business value realized (i.e. score of 2). The reasoning is equally motivated by calibration of survey data for QCA (Emmenegger et al. 2014) and qualitative reasoning among the authors that if an organization has derived “at least high value” in either PR or Sales & Marketing

(above 2), then it is more in the set of high maturity. For this first set, we coded full exclusion of 0.5 and 3.5 with a cross over point of 2.1 (Figure 6). As highlighted in Figure 6 (High Maturity), an organization with business value less than 2 is “more out than in”, while business value more than 2 is “more in than out”. The second set is organizations with very high business value realized (i.e. Very High maturity). The fact that in order to realize more than 80% businesses value it is necessary to be present on at least two social media channels (figure 5); we raise the crossover point for very high maturity stage to 3, while full exclusion for the higher end point is set at 4. Finally, in order to examine what configurations lead to low business value realized, we created measures of membership not-high and low business value realized. This third set is simply coded as the negation of the set with high maturity (Figure 4), with a full exclusion of 2.5 and 0, with a cross over at 1.5.

Next, following the calibration guidelines for QCA (Ragin 2008; Thiem and Dusa 2012), we adopt the direct method of logistic transformational assignment for assigning full exclusion, full inclusion and crossover points. While QCA literature provides with linear, trapezoidal and many more membership functions (Thiem and Dusa 2012), we chose the logistic option. The rationale for choosing logistic transformation is based on prior configurational research using fuzzy set QCA [E.g. Fiss (2011), Yi et al. (2011)] using logistic transformation over linear or trapezoidal options. Following step 4, we first calibrated Outcome (Y), then the conditions (X) and in the process also defined the maturity stages (i.e. Low, High and Very high). Translating the calibrated inclusion and exclusion scores for each of maturity stages into percentage (as indicated by dashed lines in Figure 5), we can now determine the “boundary conditions” for each maturity stage. For instance, extent of social media use (U) of more than 33.4% (i.e. score of 1.67), presence on at least one social media channel (ESC) and at least a part-time resource (FTE) forms the boundary condition for an organization to be in high maturity stage.

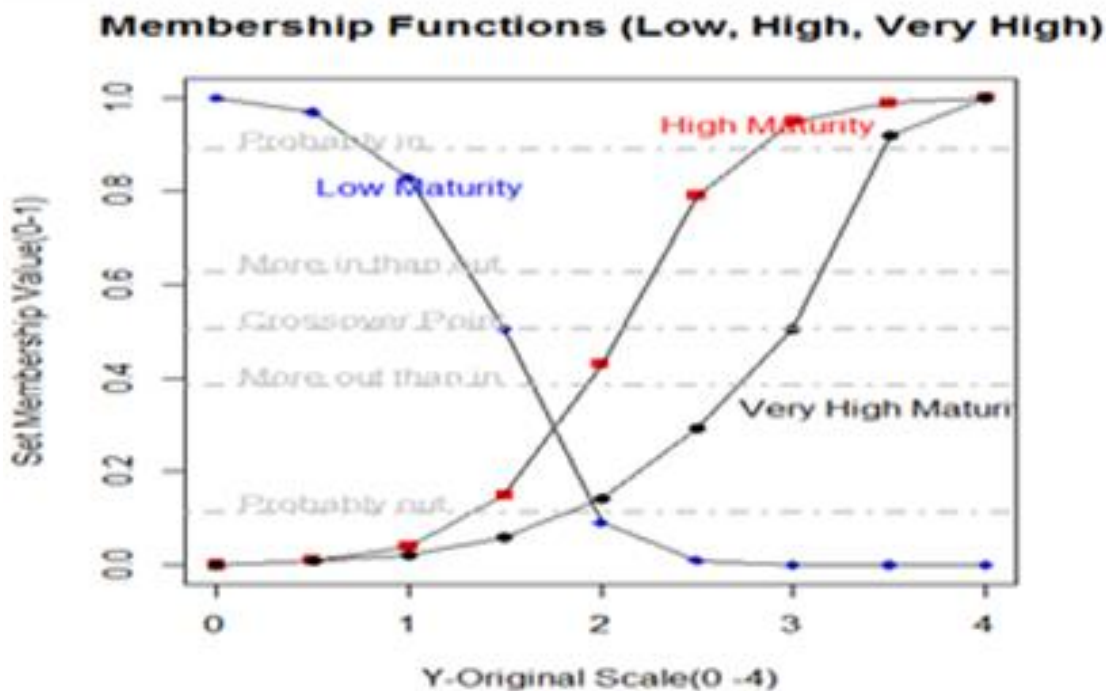


Figure 6: Calibration Logic and Maturity Stages.

The NCA findings also informed the choices regarding the calibration of some conditions (X). For example, FTE (measured as 0 for none, 1 for part time resource, 2 for one resource, 3 for two or more) is coded a full exclusion of 0 and 3, with a crossover of 0.9, indicating that at least a part time resource (i.e. score of 1) is required for an organization to achieve high maturity. Few other X's are similarly coded based on the empirical evidence at hand. Finally, calibration for some of the conditions measuring culture, top management encouragement (MUS) and skills (S) are also motivated by calibration of survey data for QCA (Emmenegger et al. 2014) and qualitative reasoning similar to the outcome (Y). For example, MUS is coded a full exclusion of 0 and 4 with a cross over point of 2; this means only when MUS is to a high (3) and very high degree (4) will it contribute as a positive case (truth table=1). Any response below that i.e., some degree (2), small degree (1) and no support (0) actually indicates that top management encouragement (MUS) is actually not visible and contribute as a negative case (truth table=0), hindering a positive outcome (Y).

Step 4b, 4c & 4d & 5: QCA & Visualizing Maturity Stages

Now that set membership score for each of the conditions (X) and the outcome (Y) has been calibrated, the next step is to translate this data into what is called a truth table. The property space for the truth table is a function of number of conditions (CSF's). A truth table contains all logically possible combinations (2^k) of k number of conditions

(Bedford and Sandelin 2015). The truth table for our demonstration dataset is created using R-QCAGUI package (Thiem and Dusa 2012). One of the difficulties routinely faced by researchers using QCA is the staggering number of logical combinations that can be generated by a relatively small number of causal conditions (Ragin 2008; Wagemann and Schneider 2010). With our demonstration dataset we had two main challenges;

1. With 14 X's, there is a limitation with number of empirical cases to get enough positive outcomes (i.e. with inclusion criteria of 0.72 and frequency threshold=1)
2. Technical limitations with available fsQCA software: A truth table as large 4,096 rows is the practical limit of fsQCA tool (Ragin 2008), while the R packages (i.e. QCA, QCAGUI or QCAPro) can handle up to 17 conditions, we are unable to get the Boolean solutions due to software limitations.

Given these challenges, the analytical strategy available at this stage is to either reduce the number of conditions (X's) by dropping or merging conditions (i.e. using AND, OR, any other set logical operations) and arriving at macro conditions (Ragin 2008). We dropped digital strategy (DS) as it did not contribute to achieving a solution and we also chose the second option and identified two macro conditions (Table 4). The first macro condition termed "FUE" is combination of common necessary conditions required to be in a high and very high maturity stages. The second macro condition "IT Policy (ITP)" is arrived through what Ragin (2008) terms "colligations", meaningful collections of facts or evidence. IT Policy (ITP) is arrived at with the logic that an organization realizing high business value from use of social media must either provide employees with devices (PEWD) or allow them to access organizational IT systems with their own devices (OD), while having a formalized IT security policy in place.

Once the macro conditions are established, step 4c requires testing for necessary conditions. This is in line with QCA's prescribed guidelines as testing for necessity should always precede the test for sufficiency in QCA (Thiem and Dusa 2012). However, in our demonstrative case, we found no single or conjunctive necessary conditions using QCA's test for necessity, while NCA identified three necessary conditions. First, this fact validates the claim by Dul (2016a) and Vis and Dul (2016) that NCA identifies more necessary conditions. Second, it reemphasizes the importance of step 2 in our six-step procedure and justifies our proposition to use NCA before applying QCA.

Table 4. Macro Conditions.

Macro Condition	Reasoning & Calibration
FUE = (U*ESC * FTE)	Extent of use (U), Presence on social media (ESC), resource for social media activities (FTE) are all common necessary conditions for high and very high maturity stage. Hence it is logical to combine the three and treat it as one macro condition as the absence of even one would mean low maturity stage. Formula: [PSF = min (U, ESC, FTE)].
ITP= [ITS*(OD+PEW D)]	With this calibration, an organization with no IT security policy would be coded 0, while an organization with a formalized and well communicated IT security policy that also provides employees with devices or lets them operate their own devices is coded 1. All other combinations are in between 0 and 1. Formula:[ITP=min [ITS*max(OD,PEWD)]

Next step in the analysis is using Boolean algebra method known as logical minimization to determine the commonalities between configurations that consistently lead to the outcome (Fiss 2011; Ragin 2008). We followed the prescribed steps (Ragin 2006; Thiem and Dusa 2012) to arrive at the final solution. The directional expectations or counterfactuals (Thiem and Dusa 2012) are coded as present (positive or +1) as all the conditions (X) are expected to be present in high maturity stage, while low maturity stage are coded as absent. It is an easy counterfactual as the decision is based on theoretical knowledge. With regards to the parameters of fit⁶² for QCA, literature suggests that the minimum consistency score should be 0.75, and there is no minimum requirement for coverage in literature (Bedford and Sandelin 2015; Rivard and Lapointe 2012). Hence we followed this benchmark of 0.75. The results from QCA give us with five solutions (i.e. configurations of conditions leading to maturity). While all the three configurations for high maturity stage (P2a, P2b, P2c) satisfied the parameters of fit, only one out of the two configurations (P1a) satisfied the criteria for low maturity stage. The existence of these multiple solutions sufficient for progression towards high maturity (configurations P2a, P2b, P2c) thus point to a notion of equifinality (Fiss 2011), justifies proposition 2 and indicates existence of multiple

⁶² Refer (Thiem and Dusa 2012) page 69-73 for prescribed tests and formulae.

paths towards maturity. Figure 7 shows the QCA final solution of high maturity and low maturity stages respectively (step 5).

Results are summarized as follows:

1. Social Media Use (U), Number of Social Media Channels (ESC) and Number of Resources (FTE) are established as necessary conditions and hence form the stage boundary conditions between low and high maturity. In practical terms, this means if an organization does not hire at least a part time resource to manage its social media, while maintaining presence on one or more social channels and showcasing some degree of use, it will not be able to progress towards high maturity.
2. Absence of Metrics (M), i.e. workflows and KPI's for social media is seen as a core condition for achieving high maturity. Formalization of social media practices and activities in an organization is considered high maturity in prior literature (Duane and O'Reilly 2012; Karkkainen et al. 2011; Lehmkuhl et al. 2013). However, these models have been developed for large organizations that lean towards formalization and streamlining of business processes. Given the flexible and entrepreneurial style of working in SME's, the newness of social media adoption in many companies, we infer that social media in itself is a new domain or business activity in most SME's and thus require fair amount of flexibility, before formalizing business processes. Moreover, social media platforms keep changing their functions and social media managers are currently expected to experiment and explore, thus justifying path P2a and P2b.
3. Management's encouragement to use social media (MUS) and increased investment (INV) are not necessary to achieve high maturity, as a path without them (configuration P2a) exists that also guarantees a path to high maturity. These results are consistent with our NCA results. Although, we identified MUS and INV as necessary conditions (effect size >0.1), we reflected and established that they are not necessary (NN) to achieve up to 60% and 70% of the level maturity, hence not a stage boundary condition for high maturity, whose boundary is drawn at 50% level of maturity.
4. With regards to Very High Maturity stage, we found no positive cases with inclusion criteria of 0.72 and hence could not propose any configurations for this stage. The only solution to this problem is going back to step 1b and expand the case selection by including organizations that have achieved very high degree of maturity. However, using the existing NCA results we established 5 stage boundary conditions to move from High to Very High Maturity (NCA). In practical terms,

this means to be in the Very High Maturity stage, an organization has to hire at least a part time resource to manage its social media activities (FTE), maintain presence on at least two social channels (ESC), showcase at least high extent of social media use (U), while having some Top Management Support (MUS) and at least have the same the investment in IT (INV) as compared to the previous year. If any of these “boundary conditions” are not met, the organization will not progress to a very high maturity stage.

CSF	Low Maturity		Paths to High Maturity		
		P1a	P2a	P2b	P2c
Technology					
Social media Presence					
Extent of Use	FUE	⊗	●	●	●
Ressource (FTE)					
Skills	SK				●
Metrics	M	⊗	⊗	⊗	
Management					
Encouragement to use	MUS	⊗		●	●
Increased Investment	INV			●	●
Culture					
Employee Driven	EEC	⊗	●		
Structured	PSC				
Explorative	NSC	⊗		●	●
IT Policy					
IT security Policy					
BYOD	ITP	⊗	●		⊗
Provide devices					
Consistency		0.84	0.76	0.78	0.80
Raw Coverage		0.07	0.23	0.36	0.29
Unique Coverage		0.03	0.09	0.02	0.04
Overall Solution Consistency		0.84		0.78	
Overall Solution Coverage		0.07		0.49	

Black circles indicate presence of a condition, and circles with “X” indicate its absence. Large circles indicate core conditions; small ones indicate peripheral conditions. Blank spaces indicate “don’t care” condition, i.e. presence or absence has no significant impact (Fiss 2011)

Consistency refers to the “degree to which cases correspond to the set-theoretic relationships expressed in a solution” (Fiss 2011) or the proportion of cases consistent with the outcome.

Coverage is the measure for the answering: “what proportion of cases with the outcome has been explained or how common is the cause among the cases with the outcome”? (Ragin 2006).

Figure 7: Low and High Maturity Characteristics.

Step 6: Operationalize the Maturity Measurement Instrument

The last step is to present the results to the main stakeholders of the academic-industry project consortium (NBI) and operationalize the instrument. It is very important to clearly understand the requirements of the main stakeholders (De Bruin et al. 2005). Therefore, as suggested, apart from direct communication with NBI, we reviewed a list of practitioner tools measuring maturity using online self-assessment surveys. We found that such tools typically require around 3 to 4 minutes of time for answering

simple questions and finally viewing the output. In line with these industry conventions, Figure 8 is an illustration of our proposal for a quick diagnostic tool for presenting set-theoretical maturity models to industry practitioners.

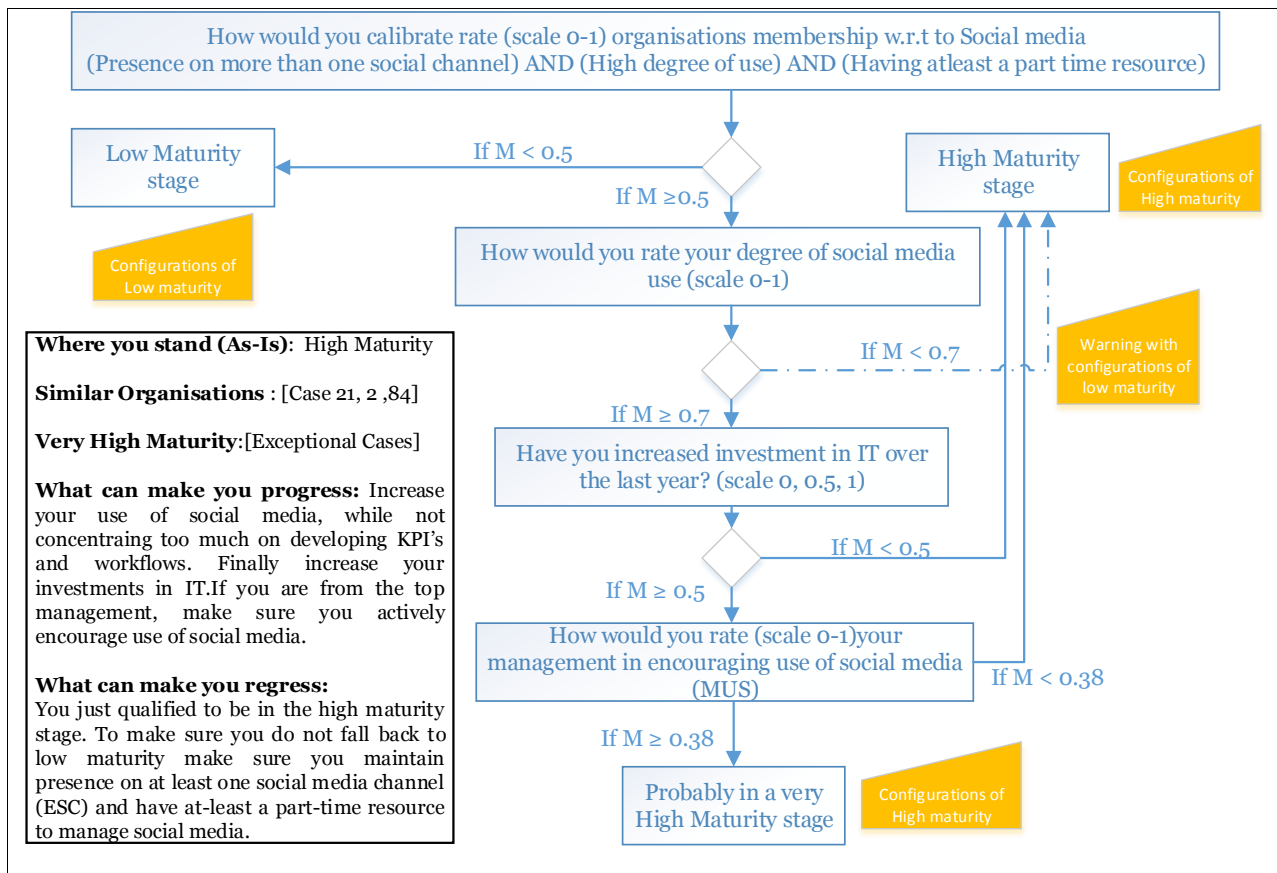


Figure 8: Illustration of the proposed maturity instrument logic.

However, as suggested by many maturity model scholars (Becker et al. 2011; De Bruin et al. 2005; Mettler et al. 2010), it is very important to test and validate the maturity design logic before operationalizing the instrument. Thus, while this paper has designed maturity logic (Figure 8) from empirical analysis of a social media maturity dataset, this is done only with the purpose of demonstrating how both researchers and practitioners can use set-theoretic methods to derive and use a maturity model. Therefore, Figure 6 should be understood as a preliminary illustration of how QCA and NCA results can be used to develop an online maturity measurement tool.

III.6 Limitations and Future Work

Although the proposed set-theoretical approach to maturity models provides major opportunities for both research and practice, we acknowledge that it entails certain challenges and limitations. First and foremost, in order to apply this method a high

level of declarative and procedural knowledge of Qualitative Comparative Analysis (QCA) and Necessary Condition Analysis (NCA) is required. The second limitation of this paper is the social media maturity dataset used. Although practically relevant and used by practitioners, the conditions are simplistic. Moreover, the dataset did not have enough positive cases to derive configurations for very high maturity stage. That said, the scope of this paper is to conceptualise maturity as concept using set-theoretic methodology and the purpose of the dataset is to demonstrate the method using a real-world dataset that is available to us. In order to address this limitation, as part of future research we will apply the six-step procedure to multiple datasets including those that have been published before in IS or related journals such as the E-Government Maturity Model (Andersen and Henriksen 2006), BI Maturity (Raber et al. 2012) and Intranet Maturity Model (Damsgaard and Scheepers 1999). Application of the six-step procedure on multiple datasets will allow us to test its generalizability. The third limitation is regarding the use of logistic transformation for calibration in our demonstration. Our rationale for this choice is rather weak and requires transformation function sensitivity analysis (Thiem 2014) which will be part of our future research. Furthermore, future work will also include applying other quantitative methods used in maturity model literature like Rasch Analysis (Cleven et al. 2014), Profile Deviation Analysis (Chen and Huang 2012), etc. on our demonstration dataset and compare the results with the set-theoretic method.

III.7 Conclusion

Recent advancements in set theory and readily available software have enabled social science researchers to bridge the variable-centered quantitative and case-based qualitative methodological paradigms in order to analyse multi-dimensional associations beyond linearity assumptions, aggregate effects, uncausal reduction, and case specificity. Based on these developments and employing methods like Qualitative Comparative Analysis (QCA) and Necessary Condition Analysis (NCA), in this paper, we proposed a novel approach to empirically deriving maturity models. The primary contribution of this paper is to the domain of maturity model research. This paper conceptualizes stage boundaries of maturity models as necessary conditions using NCA (Dul 2016c), operationalizes maturation in terms of configurations using QCA (Ragin 2008), and demonstrates the existence of multiple paths to maturity beyond a linear single path. This paper is the first attempt to apply set-theoretical methods to maturity model design and successfully demonstrates its application. It also provides

researchers with a six-step procedure with detailed guidelines to systematically apply this approach. In addition, we discuss the challenges faced in the process and offers solutions to help IS researchers interested in applying set-theoretical methods in general. The second contribution is to maturity models design. In all previous inductively derived maturity models (Cleven et al. 2014; Raber et al. 2012); the process of arriving at the number of maturity stages was arbitrary. Most models use 4 to 5 stages referencing prior models. Instead of arbitrary selection of number of stages, we provide researchers with three strategies to formulate maturity stages and their boundaries. Moreover, the iterative cycle of the proposed 6-step procedure ensures that the number of stages are analytically derived and not arbitrarily decided. A third and final contribution of this paper is to successfully compliment NCA with QCA and provide future researchers with a demonstrative use case.

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Paper IV: Whose Maturity is it Anyway? The Influence of Different Quantitative Methods on the Design and Assessment of Maturity Models

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Whose Maturity is it Anyway? The Influence of Different Quantitative Methods on the Design and Assessment of Maturity Models

Research in Progress

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Abstract

This paper presents results from an ongoing empirical study that seeks to understand the influence of different quantitative methods on the design and assessment of maturity models. Although there have been many academic publications on maturity models, there exists a significant lack of understanding of the potential impact of (a) choice of the quantitative approach, and (b) scale of measurement on the design and assessment of the maturity model. To address these two methodological issues, we analysed a social media maturity data set and computed maturity scores using different quantitative methods prescribed in literature. Specifically, we employed five methods (Additive, Variance, Cluster, Minimum Constraint, and RASCH) and compared the sensitivity of measurement scale and maturity stages. Based on our results, we propose a set of methodological recommendations for maturity model designers.

Keywords: Maturity Models, Quantitative Methods, Rasch, QCA, NCA, Fuzzy Clustering, Regression.

IV.1 Introduction

In information systems (IS) research, maturity models are understood as tools that can aid the facilitation of internal and/or external benchmarking and showcase possible improvements and providing guidelines through the evolutionary process of organizational development and growth (Mettler et al. 2010). Being normative and prescriptive by nature, development and evaluation of methodologically rigorous and empirical validated maturity models is a subject of debate and fierce critique in IS research (Becker et al. 2010; King and Kraemer 1984; Lasrado et al. 2016a), and related disciplines (Andersen and Henriksen 2006; Kazanjian and Drazin 1989; Wendler 2012). Proponents for and opponents of maturity models have long been engaged in debates on and discussions about theoretical, methodological and empirical aspects of maturity models without much comparative analysis (Lasrado et al. 2016a). In particular, maturity models are criticised for lack of theoretical foundations (Pöppelbuß et al. 2011; Renken 2004), lack of empirical validation in the selection of variables (Lahrman et al. 2011; Wendler 2012), and being overly conceptual and simplistic (Solli-Sæther and Gottschalk 2010). Recent literature reviews of the field by multiple scholars (Lasrado et al. 2015; Pöppelbuß et al. 2011; Solli-Sæther and Gottschalk 2010; Wendler 2012) point to the rarity in use of empirical or other demonstration methods. Becker et al. (2010) summarises the status quo of maturity model research as “*Information systems research has ignored theoretical approaches to maturation – the process of becoming more mature has been understood rather vaguely.... Maturity models in IS research requires analytical perspectives better grounded in theory*”. To address the criticisms of maturity models listed above, this paper investigates how maturity is currently measured employing different quantitative methods. This paper aims to conduct a systematic comparison of the five dominant quantitative methods used in maturity model research by answering the following research question: *Does the application of different quantitative methods influence the final design of maturity models and its subsequent maturity assessment?*

The rest of the paper is organized as follows. First, we summarize prior research on application of quantitative methods for maturity models. Second, we present and discuss methodological aspects of our comparative study of different quantitative methods including a description of the social media maturity dataset used. Third, we present the analysis and report the results. Finally, we discuss the results, propose recommendations, and outline future research directions.

IV.2 State of the Art: Different Methods in MM Research

Our review of maturity models in information systems research (Lasrado et al. 2016a; Lasrado et al. 2015) yielded a list of seven quantitative methods (Table 1). Two of the methods (Rasch analysis, SET) are used only for the design phase. The design phase is about empirically constructing the maturity model and involves deciding the number of maturity stages or levels, the characteristics of each of the stages, stage boundaries and the progression towards maturation. Furthermore, as illustrated in Table 1, all the seven⁶³ methods can be applied in the assessment phase. This phase involves computing the maturity scores and classifying the organisations. Finally, only one method is applied for validating maturity.

Table 1. Quantitative Methods used in Maturity Models Research.

	Method	Assumptions	Application in Information Systems
Design (D)	RASCH: Rasch analysis or Item response theory (IRT).	Organizations with higher maturity have a high probability of successfully implementing capabilities, both easy and advanced. Similarly, lower maturity ones have a very low probability of implementing advanced capabilities.	Rasch Analysis combined with Cluster Analysis was first used by Dekleva and Drehmer (1997) to empirically describe the evolution of the software development process in an organisation using capability maturity model (CMM) questionnaire. This method has then been applied by many scholars (Berghaus and Back 2016; Lahrmann et al. 2011; Raber et al. 2012).
	SET: QCA and NCA applied together.	An underlying assumption of equifinality that there exist multiple paths towards maturation.	Qualitative Comparative Analysis (QCA) with Necessary Condition Analysis (NCA) for designing a social media maturity model (Lasrado et al. 2016a). Authors prescribe a 6-step procedure for applying this method.

⁶³ Here we count EUC and SSD as one method under the category of Minimum Constraint. Although the two methods are fundamentally similar, we compare the results obtained using these two methods to assess the influence of weighting by standard deviation employed in SSD but not in EUC.

Assessment (A)	<p>CLUSTER: Two Step Clustering, Fuzzy Clustering (FC) or other methods depending on the data.</p>	<p>There are groups of organisations that are homogenous across a particular set of maturity capabilities.</p>	<p>Benbasat et al. (1980) uses cluster analysis for categorizing the companies in their study on organizational maturity on information system skill needs. Jansz (2016) adopts clustering to assess organisations' situational corporate collaboration maturity. She also provides suggestions and guidelines⁶⁴ with regards to cluster analysis preparations for handling mixed-scaled data.</p>
	<p>ADDITIVE LOGIC (ADD): Summation or average of capabilities with or without weights for capabilities.</p>	<p>There is only one single linear path to higher maturity.</p> <p>The underlying assumption is that organisations with higher maturity will have implemented more number of capabilities.</p>	<p>Summation, simple average, and weighted average wherein the formulation of weights is arbitrary or non-empirical (Chung et al. 2017; Luftman 2000; Van Steenberg et al. 2013) are commonly used for maturity assessments. Empirically supported calculation of weights using methods like structural equation modelling (Winkler et al. 2015) is rare.</p>
	<p>MINIMUM CONSTRAINT: (a) Statistical</p>	<p>There is only one single linear path to higher maturity.</p> <p>The underlying principle is based on</p>	<p>There is only one instance each for application of SSD (Joachim et al. 2011) and EUC (Raber et al. 2013) who also prescribe a detailed 3-step procedure for SSD and EUC respectively. The only difference</p>

⁶⁴ For the dataset used in our study, we chose Fuzzy Clustering (FC) as it is prescribed as an approach to identify complex non-linear phenomena. According to Babuška (2012), fuzzy clustering does so by partitioning the available data into groups and by approximating each group using a simple model. It can be used as a tool to partition the data in such a way that the transitions between the groups is smooth rather than abrupt. It can be used to both design a maturity model as well as classify maturity of organizations. Fuzzy clustering has prescribed validity measures (Wang and Zhang 2007) such as Partition Coefficient, Partition Entropy (Bezdek 2013) and Xie and Beni's Index (Xie and Beni 1991) to validate and identify the suitable number of clusters. In this paper, we have used Fuzzy C-means clustering algorithm (Bezdek et al. 1984) to partition the data pertaining to digital maturity of organizations.

	Squared Distance (SSD) (b) Euclidian Distance (EUC)	theory of constraints; the overall maturity is the level of maturity of the lowest capability.	between the two methods is that SSD is weighted by the standard deviation at the capability level and EUC does not.
Validation (V)	VARIANCE: Regression, Correlation coefficients with tests for statistical significance	Organizations with high maturity will also realise higher business benefits, performance and business value as compared to the ones at a lower maturity level.	Validating maturity using regression (Chen 2010; Joachim et al. 2011; Raber et al. 2013; Sledgianowski et al. 2006) or correlation coefficients (Marrone and Kolbe 2011) against self-reported maturity, perceived benefits or performance.

IV.3 Methodology & Dataset Description

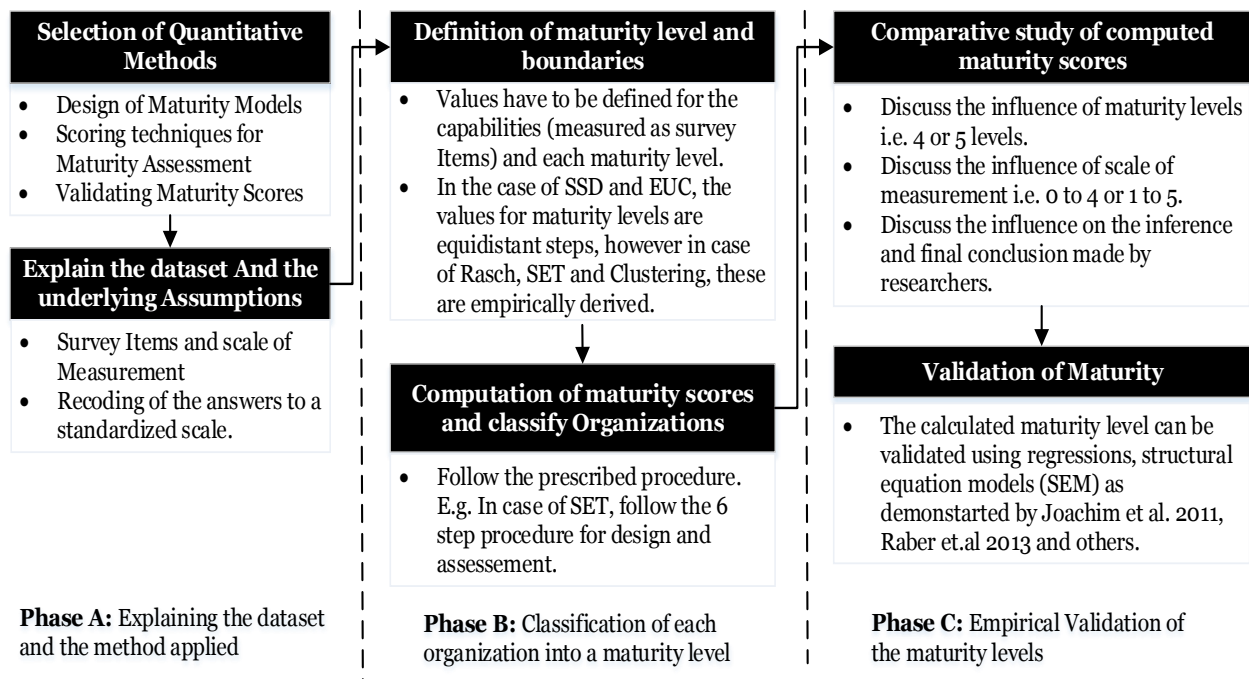


Figure 1. Methodological Framework for the Multi-Method Comparative Study.

To answer our research question, we employed a multi-method comparative approach on a single dataset. Our methodological approach is similar to the one adopted by Van Looy (2015) to study business process maturity scoring algorithms. However, instead of a single case study, we used a dataset measuring social media maturity of 85 organizations in Denmark (Lasrado et al. 2016a). Given the quasi-experimental design, we held the dataset constant and varied the quantitative methods. Overall our methodology comprised of three phases as summarized in Figure 1 and discussed below.

Phase one of our methodology involves the selection of the quantitative methods from a review of the extant literature and then explaining the dataset. We select and apply all the seven methods listed in Table 1 on a dataset measuring social media maturity by Lasrado et al. (2016a). This data was collected through a cross-sectional survey whose primary purpose was comparative benchmarking of participating organizations in Denmark. As illustrated in Table 2⁶⁵, there are 14 conditions or capabilities (X) grouped under 4 broader categories: Management, IT Policy, Technology and Culture. In line with our previous research papers (Lasrado et al. 2016a; Lasrado et al. 2016b) using the same dataset, we also employ business value realized in PR, Sales & Marketing (Y) as a proxy measure for maturity.

Table2. Dataset and Conditions Explained (Lasrado et al. 2016a).

	Condition (X)	Scale; # of items	Study Recoding
Culture	The measures for Culture are based on orientation towards employee driven style of working and decision making (EEC), a well-planned and structured style (PSC), and an explorative culture (NSC) wherein new IT systems are always sought after. They are measured as Completely disagree (-2) to Completely	EEC: Likert Scale (-2 to 2); 4	0 = 0; -1 = 1; 0 = 2; 1 = 3; and 2 = 4. In case of decimals, then <i>round off</i> to the nearest integer. E.g. If EEC = 1.4, then it is rounded off to 1, if ≥ 1.5 and above then 2.
		PSC: Likert Scale (-2 to 2); 2	
		NSC: Likert Scale (-2 to 2);	

⁶⁵ Given the page constraints of a research-in-progress paper, we can only briefly list and explain the capabilities or conditions and their respective scales of measurement in Table 2. Furthermore, for the purpose of standardisation, we also recoded the original dataset as integers between 0 and 4. The reason for this standardisation step was to facilitate application of Rasch Analysis as there is a strict requirement that the items need to be integers.

	agree (2).	1	
Management	Top Management encourages use	Likert (0-4); 1	Not Recoded.
	IT investment within the organization as compared to previous years	0=decreased,1=Same, 2=increased; 1	0=decreased,2=Same, 4=increased.
	Digital strategy Index (DS)	Index (0 to 4); 1	Round off i.e. DS=2.6, then rounded off to 3.
IT Policy	Allowing access to Own Devices (OD) measured on access to number of systems, and/or Providing Employees With Devices (PEWD) measured on number of employees, while having a high IT Security Index (ITS) is an organization with high social media maturity.	ITS: Index (scaled to 4); 1	Round off i.e. DS=2.6, then rounded off to 3.
		PEWD: Likert Scale (0-4); 1	Not Recoded.
		OD: Likert Scale (0-4); 1	Not Recoded.
Technology	Social media presence, measured as the number of social media channels.	Count (0 -8); 1	0 = 0; 1 = 1; 2 = 2; 3 = 3; $\geq 4 = 4$.
	Extent of Use of social media.	Likert Scale (0-4); 2	Round off.
	Number of resources (FTE) hired specifically for social media activities, measured as none, part time, full time and more than one.	Ordinal (0,1,2,3,4); 1	Not Recoded.
	Sometimes, a marketing manager or any other employee manages social media. Hence professional skills (S) available inside the	Likert Scale (0-4) i.e. Not at all to Very high degree; 1	Not Recoded.

	organization is measured.		
	Metrics (M) is a measure of formalized governance i.e KPI's, and workflows	Ordinal (0,0.5,1); 2	0 = 0; 0.5 = 2; 1 = 4
Y	Business Value from social media in customer facing activities.	Likert Scale (0-4); 2	Round off.

IV.4 Analysis & Results

We now present and discuss Phases B & C in Figure 1. All the different methods discussed in section 2 were applied on the social media maturity dataset. However, Rasch analysis proved to be ineffective in providing valid and reliable results. The reason for these ineffective results is that the survey items were not designed keeping Rasch analysis in mind, especially in keeping the scales and their intervals constant. Hence Rasch analysis was dropped from this comparative study. However, we successfully designed and assessed social media maturity of organisations using set theory (SET) while satisfying all the validity tests prescribed.

The success of SET over Rasch⁶⁶ can be mainly attributed to the steps involving QCA, specifically qualitative interference and calibration that makes the dataset less vulnerable to measurement errors, outliers and inconsistent scales across different survey items. Using SET, we empirically derived four maturity stages and classified organisations as belonging to one of these stages or levels. Next, we applied fuzzy clustering and established existence of two maturity stages. Finally, we applied statistical squared distance (SSD), Euclidian distance (EUC), and additive logic (ADD) methods to assess maturity and the results are discussed below.

IV.4.1 Comparison of Maturity Assessment Results

Comparison of the maturity assessment results using the five methods is illustrated in Figure 2. It is quite evident that the five methods produce very different results. While set theory (SET) classifies organizations across four stages ranging from no maturity to

⁶⁶ Rasch algorithm checks for the sensitivity of the final results using measures of person and item reliability (Cleven et al. 2014). A reliability greater than 0.8 is expected. However, for the social media maturity dataset, we obtained a reliability of 0.44 which is way below the prescribed minimum.

very high maturity, the other four methods (ADD, EUC, Fuzzy Clustering and SSD) classify majority of the organizations as high maturity. We find that set theory (SET) is the most conservative of all the methods with 43% of the organizations at the lowest level of maturity while ADD is the most lenient with 60% of the organizations classified as high maturity.

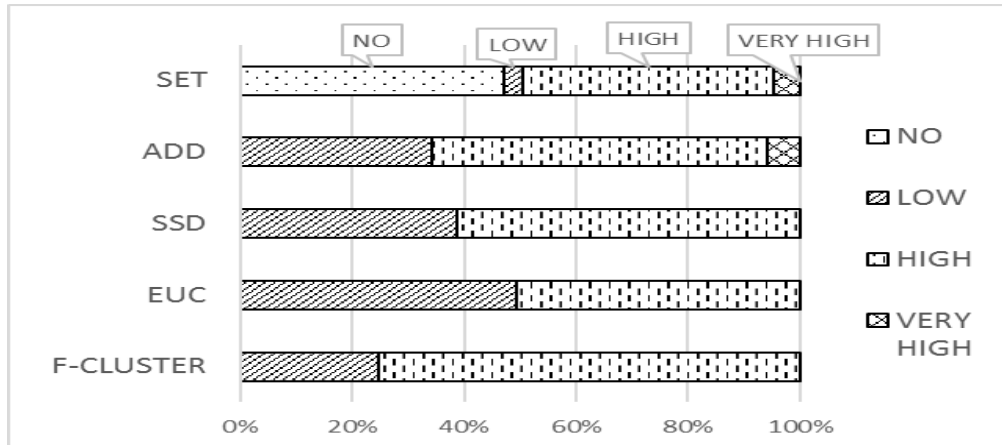


Figure 2. Variation in Maturity Assessment using Five Different Quantitative Methods.

We then investigated the commonalities or intersections of the 5 methods and found that only 25 of the 85 organisations (i.e. 29%) share common maturity results. Furthermore, a detailed inspection of intersections (denoted with \cap) provided us with other interesting findings; (1) $EUC \cap \text{Fuzzy Clustering} = 50$ (59%), (2) $EUC \cap SSD \cap ADD \cap \text{Fuzzy Clustering} = 44$ (52%), and (3) $EUC \cap SSD \cap ADD \cap SET = 27$ (32%). These results highlight the fact that the quantitative method chosen exerts a substantial influence on the final maturity assessment.

IV4.1.1 Effect of Measurement Scale

Next, we investigated the. In particular, we investigate the impact of the two scale designs of 0-4 vs. 1-5 while keeping the intervals equidistant⁶⁷. Prior research on effect of measurement scales on BPM maturity (Van Looy 2015) found that maturity scores are generally lower for a 0-4 scale than a 1-5. We tested this finding for our five quantitative methods. We find that change in measurement scale has no impact whatsoever on the maturity results using any of the four methods (ADD, SSD, EUC

⁶⁷ E.g. Business Value is measured as None (0), Low Value (1), Some Value (2), High Value (3), Very High Value (4). By changing to a 1-5 scale, we just add 1 to all values i.e. None (1), Low Value (2), Some Value (3), High Value (4), Very High Value (5).

and SET). Now that the effect of scale of measurement has been tested, next we investigated the effect of the number of maturity stages.

IV.4.1.2 Effect of Number of Stages

The decision about selecting the number of maturity stages forms the core of any maturity model design framework (Cleven et al. 2014; Lasrado et al. 2016a). In order to test the effect of number of stages on final maturity assessments, we compared the maturity scores for 4 vs. 5 stages. While such a comparison is not possible for Fuzzy Clustering and SET method as the number of stages are empirically derived and not arbitrarily chosen, we were able to test the effect of the number of maturity stages for EUC, SSD and ADD⁶⁸. We find statistically significant differences⁶⁹ with an increase of overall average maturity by 39.75%, 28% and 36.7% observed for EUC, SSD and ADD respectively as maturity stages are increased from four to five. These findings highlight a critical issue raised by many scholars (Cleven et al. 2014; De Bruin et al. 2005; Solli-Sæther and Gottschalk 2010) that the researcher's choice of number of maturity stages should not be arbitrary but theoretically informed during the design or assessment phase and should be empirically validated subsequently. Now that effect of number of maturity stages is established, we then conducted the validation of maturity using different methods.

IV.4.2 Validation: Maturity Results and Perceived Business Value

While Maturity Models literature predominantly uses qualitative methods (e.g. focus groups, Delphi method and interviews) for validation of maturity, there have been few scholars (Table 1) who have employed quantitative variance based methods (e.g. Correlation, OLS, and SEM). Although this approach to validating maturity has been critiqued and challenged (King and Kraemer 1984; Mullaly 2014), it is the sole quantitative method for validation used in literature till date. In line with recommendations from prior research (Joachim et al. 2011; Raber et al. 2013; Winkler et al. 2015), we investigated the relationship between social media maturity and

⁶⁸ EUC_2 indicates 1-5 scale. SSD_2 also indicates 1-5 scale with 5 maturity stages.

⁶⁹ There was a significant difference in the maturity scores calculated using SSD_1 (M =1.61, SD =0.49) and SSD_2 (M =2.06, SD =0.496); $t(84) = -8.241, p = 0.000$. Similarly, T tests for EUC_1(M =1.51, SD =0.503) and EUC_2 (M =2.15, SD =0.567); as well as ADD_1(M =1.72, SD =0.569) and ADD_2 (M =2.31, SD =0.655) highlighted significant differences.

business value (DV) using SEM analysis by Partial Least Square (PLS) technique (Hair 2011). The results are listed in Table 3.

As illustrated in Table 3, maturity assessments done using the four methods of Fuzzy Clustering, SET, ADD and SSD are validated irrespective of the number of maturity stages. Interestingly, a drastic drop of R-Sq (adj) in EUC and EUC_2 is observed. Hence, EUC could not be validated as the R-Sq (adj) of 0.085 is considered very weak and below the threshold of 0.1. This is primarily attributed to the way maturity scores are calculated for this method. The theory of constraints (Van Looy 2015) plays an important role wherein the minimum scores of the dimensions pull the final maturity scores lower.

Table 3. Validation of Maturity.

Method		# Stages	Scale	Mean	Std. Dev	Coefficient t	R-Sq (Adj)
EUC	EUC	4	0-4	1.51	0.503	0.291*	0.085
	EUC_1	4	1-5	1.51	0.503	0.291*	0.085
	EUC_2	5	1-5	2.15	0.567	0.300*	0.090
SSD	SSD	4	0-4	1.61	0.490	0.420*	0.176
	SSD_1	4	1-5	1.61	0.490	0.420*	0.176
	SSD_2	5	1-5	2.06	0.496	0.365*	0.133
ADD	ADD	4	0-4	1.72	0.569	0.377*	0.142
	ADD_1	4	1-5	1.72	0.569	0.377*	0.142
	ADD_2	5	1-5	2.31	0.655	0.457*	0.209
SET		4	0-4	1.07	1.055	0.468*	0.219
Fuzzy Clustering		2	1-5	1.75	0.43	0.541*	0.29
*p-value significant at 95% level of confidence. R-Sq indicates amount of variance explained (min value 0.1) and Path coefficients indicate the strengths of the relationships.							

IV.5 Recommendations and Future Research

Going beyond a simple comparison of different maturity measurement methods, based on the empirical findings reported and discussed above, we propose a list of recommendations for maturity model designers in Table 4 below.

Table 4. Recommendations for Maturity Model Designers

Key Question	EUC	SSD	ADD	SET	RASCH	CLUSTER
Is the method suitable for Design (D) or Assessment (A) phase?	A	A	A	D+A	D+A	D+A
Is the selection of number of maturity stages arbitrary (M) or empirically driven (P)?	M	M	M	P	M	P
Has the approach prescribed the necessary validity and reliability tests for the measures? <i>Yes (Y), No (N), Don't know or Not tested in this study (-).</i>	N	N	N	Y	Y	Y
Does the approach need a dependant variable (DV) for design and/or assessment?	N	N	N	Y	N	Y
Would change in scale impact results?	N	N	N	N	-	-
Would change in # of stages impact results?	Y	Y	Y	-	-	-

There are two limitations of this study. First, not all the propositions related to maturity model design and assessment could be addressed in this paper, especially with regards to Rasch Analysis. This limitation is primarily due to the social media maturity dataset used for this study failing to satisfy the prescribed validity and reliability measures. Second, the findings and subsequent recommendations are solely based on using single maturity dataset, and limited to only five different maturity computation methods. In order to address these two limitations, future research would be repeat the three phase

methodological process on multiple datasets spanning academia (ITIL Maturity (Marrone and Kolbe 2011; Wulf et al. 2015) and industry (Omni channel Maturity (Houllind 2015)). Future work will also investigate incorporating new computational methods and techniques.

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Paper V: Set-Theoretic Approach for Uncovering Prior Research Claims on ITIL Maturity

Under Review at AIS Transactions on Replication Research Journal (Single-Author).

Set-Theoretic Approach for Uncovering Prior Research Claims on ITIL Maturity

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Abstract

This paper replicated and extended a study on ITIL maturity conducted in 2009 (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b). This conceptual replication tested the same research propositions on the original dataset, but using a different meta-theory and method. At the same time, this paper cleaned the original dataset further and improved the validity of the findings. This replication paper argued for use of multi-condition analysis techniques over single condition analysis so as to provide a holistic understanding of the phenomenon being investigated. In particular, it employs a configurational theory perspective of ITIL maturity and uses the set-theoretic approach to test its associations with conditions like business benefits, business-IT alignment, ITIL processes implemented, and challenges for their implementation. The paper concludes with a few reflections on the lessons learnt during the process and implications for replication studies in general.

Keywords: Maturity Models, QCA, NCA, ITIL, ITSM, Replication.

V.1 Introduction

Replication research is argued to be a crucial and standard practice to the advancement of science and recently, scholars (Dennis and Valacich 2014; Niederman and March 2015) have argued for the need of replication in the Information Systems (IS) discipline. These scholars further argue that replication studies can provide “external third-party validation of the results of published scientific articles and also offer generalization of the original contribution into a new context” (Vedadi and Warkentin 2016). In order to facilitate replication research in IS, Dennis & Valacich (2014) have classified replication research into three fundamental categories; exact, methodological, and conceptual.

Exact replications are copies of the original analysis in terms of method and context; and the findings are compared. Methodological replications use exactly the same methods (measures, treatments, statistical analyses remain identical) but the context in which the study is conducted is changed. Conceptual replications test the same research questions (hypotheses) as the original study, but use different methods (measures, treatments, statistical analyses) and might also change the context (Dennis and Valacich 2014; Niederman and March 2015). Dennis & Valacich (2014) argue that conceptual replications are the strongest form of replication as they attempt to both “test the boundaries of the theory and the strength of a relationship”. Furthermore, Niederman and March (2015) argues for use of different types of meta-theory (research perspectives) and methods to compare findings with original research and make an additional contribution to theory.

The central theme of this replication study is ITIL maturity. ITIL is a set of defined practices employed to implement IT service management (ITSM). ITIL was first published in the 1990s, with the second version (ITILV2), launched in 2000. ITILV2 (Service Support and Service Delivery processes), also known as ITIL Books, are highly popular among practitioners and have become de-facto standards in the industry (Wulf et al. 2015). A process maturity scale is employed to measure implementation of ITIL processes, with maturity model as a practical tool to describe levels of evolutionary improvement (Marrone and Kolbe 2011a; Wulf et al. 2015).

This current study follows the conceptual replication and replicates a study on ITIL maturity conducted in 2009 (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b). This current study follows the conceptual replication and replicates a study on ITIL maturity conducted in 2009 (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b).

Following conceptual replication, this study tests the same research propositions using the same data, but using a different meta-theory and different method. In terms of meta-theory, the original study focused on variance theory perspective, using univariate methods to test relationships between individual conditions and ITIL maturity. This replication research study takes a configurational theory perspective (El Sawy et al. 2010; Fiss 2011), and employs set-theoretic method (Ragin 2008a; Vis and Dul 2016) to extract complex configurations. The study tests relationships using multi-condition analysis (similar to multivariate in statistical analyses). Furthermore, the measures are also slightly modified, with two extra conditions (time since adoption and process maturity) being included in the analysis. In addition to this, conditions used by the original study are also modified to extract additional insights. For example, the original study groups both Service Support (SS) processes and Service Delivery (SD) processes as one condition, whereas this study uses them as two separate conditions. Similarly, the challenges to implementation of ITILV2 is modelled separately as funding (FUND) and organizational (ORG) challenges in this study. By doing so, this replication study incorporates the complexity of real social science in the analyses, moves beyond the single variable (or condition) analyses performed in the original study and as a consequence contributes to a better and improved ITIL maturity model.

The rest of the paper is structured following the guidelines prescribed by Niederman and March (2015). First, the theory, context and methodology of the original study is discussed. Second, the procedures used in this replication study is explained. This includes the discussion of data used, and analyses techniques employed. Third, the replication results are presented. Finally, the paper concludes by comparing the results and discussing future directions.

V.2 Overview of Original Research

The original empirical study (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b) focused on ITIL (V2 and V3); the most popular ITSM framework. Their research focus on understanding the relationship between different levels of maturity of ITIL implementation and associated factors like; challenges of implementing ITIL, number of implemented processes, business-IT alignment and business benefits realized as companies increase the adherence to the ITIL maturity levels. The ITIL maturity model presented by Marrone and Kolbe (2011a) was based on the model from CobiT and Capability Maturity Model Integration (CMMI) with maturity levels acting as profiles of IT processes implemented. The maturity levels were referred to as non-

existent (0), initial (1), repeatable (2), defined (3), managed (4), optimized (5) and their descriptions/definitions are illustrated in table 1.

Table 1: ITIL maturity model levels (Marrone and Kolbe 2011a).

Stage	Stage name	Description of the Stages
0	Non-existent	Management of processes is not applied at all
1	Initial/ad hoc	Processes are ad hoc and disorganized
2	Repeatable	Processes follow a standard, are documented and understood
3	Defined	Processes are documented and monitored for compliance
4	Managed	Management monitors and measures according to metrics established on the previous level
5	Optimized	Good practices are followed and automated

Marrone and Kolbe (2011a) reviewed relevant research on ITSM/ITIL and formulated a number of propositions with regards to (i) Implemented Processes and Maturity Level, (ii) Perceived Challenges and Maturity Level and (iii) Number of Realized Benefits and Maturity Levels. In their subsequent paper, Marrone and Kolbe (2011b) formulate propositions on ITIL maturity level and Business-IT alignment. The thinking behind all the propositions were mostly linear and additive. For example, Marrone and Kolbe (2011a) state that an organization would select and implement processes which would, in their opinion, provide their companies with the biggest benefits. Therefore, they expected that as an organization progresses towards higher levels of ITIL maturity, it would implement more ITIL processes, overcome the challenges that hamper its implementation, achieve higher business-IT alignment and thus realize more business benefits. They (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b) provide strong theoretical arguments for their propositions. For example, based on the learning effect model or experience curve (Wright 1936), Marrone and Kolbe (2011a) argue that an organization gains experience and becomes more efficient over time, allowing for the perception of the challenges to decrease. In the case of ITIL, they formulate their first proposition (P1) as: “There is a negative relationship between maturity levels of the ITIL implementation and perceived challenges of implementation” (Marrone and Kolbe 2011a). They list seven challenges of implementing ITIL based on prior research (listed in table 2 and appendix 1). Similarly, the following propositions are formulated:

P2: There is a positive relationship between implemented processes and perceived maturity of the ITIL implementation.

P3: Based on the perception of the IT organization, as the maturity level of ITIL increases, the Business-IT alignment increases.

P4: There is a positive relationship between maturity levels and perceived realized benefits.

In order to empirically test the propositions, Marrone and Kolbe (2011a) designed an online questionnaire and collected data from 503 ITIL champions between April and May 2009. The structure of the questionnaire addressed ITIL adoption, usage, implementation, maturity and effectiveness of processes, Business-IT alignment and realized benefits (Appendix 1). The survey also covered other topics but in this paper, I consider questions that were used in the two articles (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b). The survey questions measured responses using Likert scales and ordinal scales (check appendix for questions). Of the 503 responses, Marrone and Kolbe (2011a) used all 491 respondents for their analysis (ITILV2 = 248, ITILV3 = 193, and none = 50), while Marrone and Kolbe (2011b) restricted their analysis to the ones who had adopted ITILV2 or TILV3, thus using 441 responses (ITILV2 = 248 and ITILV3 = 193). The survey data was then analyzed using the Kruskal-Wallis and Mann-Whitney tests to complete comparisons within the different implementation levels. The comparisons were tested between the first (1), middle (3) and final levels (5) of ITIL implementation maturity. Results were analyzed and outcomes discussed (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b). The results are summarized as follows:

R1: The challenges for ITIL implementation decreases as the maturity levels increase.

R2: There is a positive relationship between the number of implemented ITIL processes and the maturity level of the ITIL implementation.

R3: Maturity of ITIL is positively associated with Business-IT alignment. The greatest increase of the perceived level of maturity is observed when comparing Level 3 (Defined) and Level 5 (Optimized).

R4: The number of realized benefits increases as the maturity level increases. However, there is no significance when comparing the later levels of maturity, Level 3 (Defined) with Level 5 (Optimized).

The findings are regardless of the version of ITIL implemented (ITILV2 and V3). Both the papers find similar relationships for both versions of ITIL.

V.3 Overview of this Replication Research

In both their original papers, Marrone and Kolbe (2011a) and Marrone and Kolbe (2011b) use univariate methods for analyzing the data and making their conclusion. However, social scientists would argue that while single variable (or condition) analysis is of analytical value, it may not be considered inadequate as real social science is more complex (Ragin 2006; Ragin 2008b). Therefore, in this study we analyse the same dataset used by Marrone and Kolbe (2011a) using set theoretic approaches, in particular Fuzzy-set Qualitative Comparative analysis (FsQCA) and Necessary Condition Analysis (NCA). FsQCA is designed to compare multiple cases and conditions in terms of complex configurations (Bedford and Sandelin 2015) and thus is an adequate method for this study. The analysis in this paper follows the six step procedure and guidelines (Lasrado et al. 2016a) prescribed for a set theoretical approach to maturity models.

V.3.1 Research Method: Set Theoretic Approach to Maturity Models (STAMM)

(Lasrado et al. 2016a) developed six step modeling procedure for designing maturity models and is represented in the form of a flow chart, as illustrated in figure 1.

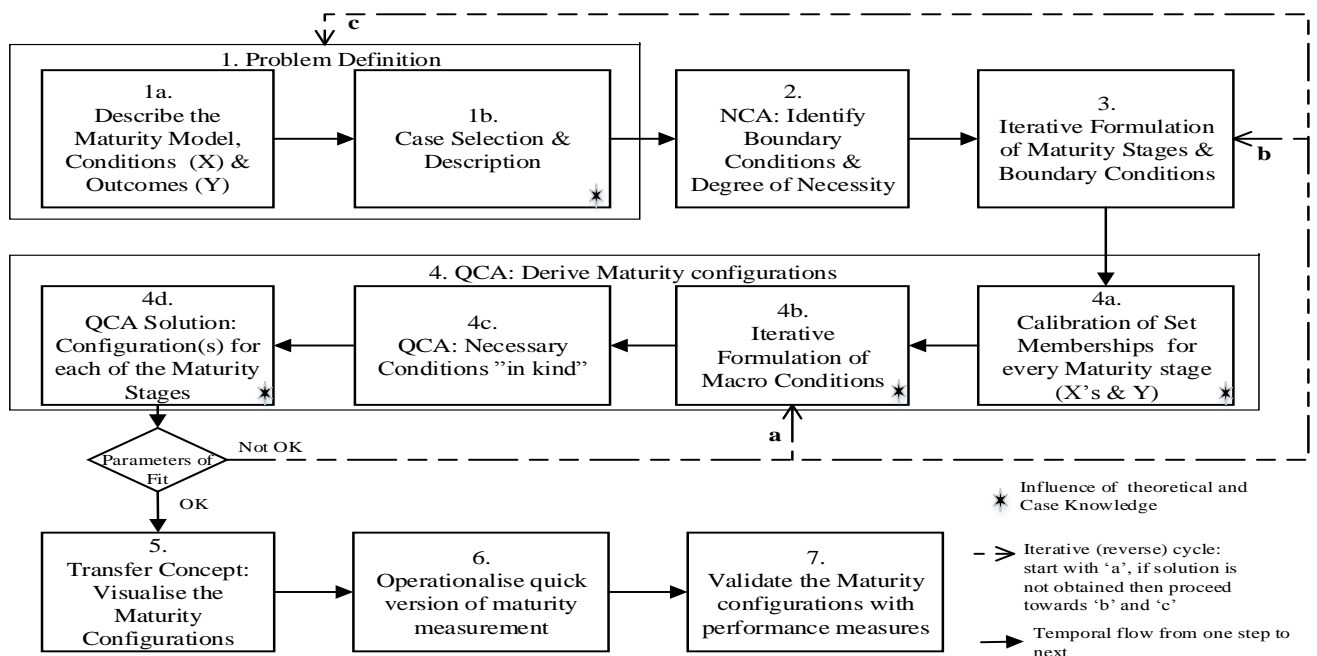


Figure 1: Set-theoretic approach to maturity models. Adopted from (Lasrado et al. 2016a)

According to Lasrado et al. (2016a) "the elements of the six-step procedure are informed by (a) detailed review of guidelines and procedures for developing maturity models (Becker et al. 2009; Mettler et al. 2010; Solli-Sæther and Gottschalk 2010), (b) guidelines for standard practices in QCA (Fiss 2011; Goertz 2006; Thiem and Dusa 2012; Wagemann and Schneider 2010), and (c) guidelines for NCA (Dul 2016c; Vis and Dul 2016)". In the context of this paper, the six step modeling procedure is extended to seven as illustrated in figure 1 (the final step of validation is added). The first step (1a) requires the researcher to describe the underlying research model including the conditions (X) and outcomes (Y). This step (1b) also requires the researcher to describe the case selection process; i.e. describe the dataset and research design. For this replication study, a detailed description of the dataset used and research design is provided in section 3.2 and 3.3. The next four steps (step 3, 4, 5 and 6) provide detailed guidelines for analysing the data. This paper follows the guidelines provided (Lasrado et al. 2016a) for analysis and the steps are discussed in the results section.

V.3.2 Describing the Dataset

This replication study analyses only ITILV2 and then compares the findings with the original research (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b). There are two reasons for analyzing only ITILV2; (i) during the time of data collection, ITILV2 was a well matured concept and understood well across organisations, as compared to ITILV3 which was just introduced (about 6 months to 1 year before data collection in April 2009) and (ii) as a consequence, the ITILV3 respondents were not asked to answer questions regarding the maturity of the processes implemented. However, before starting the analysis, the original sample (ITILV2 = 248) is further cleaned. First, after a discussion with the original researchers (Marrone and Kolbe 2011a), respondents that had a job role of help/service desk operative (ITILV2) were removed from the dataset, resulting in 7 responses being dropped. Furthermore, 12 more responses were identified as not valid and excluded. The final data consisted 229 respondents for ITILV2 as illustrated in table 2.

Table 2: Profile of responding organizations ($n_{V2}=229$).

Industry	%	Countries	%	# of sites	%
Technical	31	United Kingdom	62	10+	68

Public	25	United States	28	2-5	18
Financial and Banking	17	Others	10	6-10	8
Professional	5			1	6
Retail and Distribution	5	# of employees	%	Job Role	%
Entertainment	3	10000+	36	IT director	12
Manufacturing	3	5001-10000	18	IT manager	34
Utility	2	1001-5000	22	Process manager	24
Healthcare	2	501-1000	10	Service delivery	19
Telecommunication	2	101-500	9	Help-desk manager	11
Other	5	<100	3		

3.3 Research Model: Conditions (X) and Outcome (Y)

The ITILV2 maturity dataset consists of 8 conditions (X's) and one outcome (Y) as listed in Table 3. The outcome (Y) is overall ITIL maturity and is measured as 5 levels that range from non-existent (0) to optimized (5) and is measured using a 5-point likert scale (Appendix 1: Q1).

Table 3: 10 Conditions (X) associated with ITIL Maturity (Y).

Condition (X)			Measured as
Processes Implemented	ITILV2 Service Support processes that have been implemented. Service Support include five processes; Incident Management, Problem Management, Change Management, Release Management, and Configuration Management.	SS	Count (0-5)
	ITILV2 Service Delivery processes that have been implemented. Service Delivery processes include five processes; Availability Management, Capacity Management, Financial Management, Service Level	SD	Count (0-5)

	Management, and IT Service Continuity Management.		
Process Maturity	Maturity level of Service Support processes implemented. The final maturity of Service Support processes is an average of maturity level of each of the Service Support processes that have been implemented.	SSM	Likert (1-5)
	Maturity level of Service Delivery processes implemented. The final maturity of Service Delivery processes is an average of maturity level of each of the Service Delivery processes that have been implemented.	SDM	Likert (1-5)
Challenges	Resolving perceived funding challenges or barriers for ITILV2 implementation. They are calculated as the count of funding challenges resolved; i.e. lack of executive sponsorship, lack of funding/cost of adoption and lack of resources (time or people).	FUND	Count (0-3)
	Resolving perceived organisational challenges or barriers for ITILV2 implementation. They are calculated as the count of organisational challenges resolved; i.e. lack of business understanding ITIL, lack of of internal skills/knowledge relating to ITIL, organizational/cultural resistance, and lack of momentum.	ORG	Count (0-4)
Alignment	Business-IT alignment measures the engagement of creating and supporting the activities that fit the strategy between the business and IT. The perceived level of Business-IT alignment is based on Luftman (2000)'s SAMM levels.	BITA	Likert (1-5)
Time	Time since adoption of ITILV2. Measured using an ordinal scale with options (i) over five years ago, (ii) 2 to 5 years, (iii) 1 to 2 years, and (iv) within the last year.	Time	Ordinal (4,3,2,1)

Finally, the results (i.e. maturity configurations) were validated against business benefits realised from implementing ITILV2. The rationale behind this is similar to Lasrado et al. (2016a)'s assumption about maturity: "Maturation means the path to

something better”, which translated to the current context would mean “overall ITIL maturity \propto business benefits”. While Lasrado et al. (2016a) used business benefits as a proxy measure for maturity, in this study it is used only to validate the maturity results. The question on business benefits focuses on the total number of realized benefits due to implementation of ITIL. Marrone and Kolbe (2011a) argue that progression of ITIL maturity would mean increase in total number of realized benefits (Appendix 1: Question 1).

V.4 Analysis and Results

V.4.1 Necessary Condition Analysis (NCA)

As mentioned, in this analysis the seven step procedure is employed (figure 1). First, NCA is employed to identify single necessary conditions (step 2). “NCA” is a technique for identifying relationships of necessity that can make both statements in kind and in degree (Dul 2016a). NCA uses Data Envelopment Analysis (DEA) based techniques. “Necessary conditions are identified by examining the NCA graphs (X-Y plots) and then evaluating the effect size. Effect size is the measure of the area of emptiness in the top right corner of the X-Y plot and is calculated by drawing ceiling lines enveloping the data” (Dul 2016c; Lasrado et al. 2016a). Various techniques and reasoning for using them are prescribed in the R package (Dul 2016b) for NCA. “Depending on how the condition is measured (i.e. discrete or continuous) and the interpretability of the results, the appropriate type of ceiling line (i.e. CE-FDH, CR-FDH or any other) is selected (Dul 2016c; Lasrado et al. 2016b). Finally, the level of conditions (X) that are necessary are listed against the outcome (i.e. level of maturity) and reflected upon in a tabular format (Lasrado et al. 2016a) as illustrated in table 4.

Table 4: Bottleneck Table: ITIL(Y) vs. Conditions(X).

ITIL	SSM	SS	SD	SDM	Time	BITA	FUND/ORG
1	NN	NN	NN	NN	NN	NN	NN
1.4	NN	NN	NN	NN	NN	NN	NN
1.8	NN	NN	NN	NN	NN	NN	NN
2.2	NN	NN	NN	NN	NN	NN	NN
2.6	NN	NN	NN	NN	NN	NN	NN

3	0.12	NN	NN	NN	NN	NN	NN
3.4	0.792	1	NN	NN	NN	NN	NN
3.8	1.464	1	NN	NN	NN	NN	NN
4.2	2.136	2	NN	NN	3.0	3.0	NN
4.6	2.808	2	NN	NN	3.0	3.0	NN
5	3.48	2	NN	NN	3.0	3.0	NN
Effect Size	0.18	0.15	NA	NA	0.167	0.01	NA
Ceiling Line	CR-FDH	CE-FDH	NA	NA	CE-FDH	CE-FDH	NA

ITIL: ITIL Maturity; NA: Not Applicable because it is Not Necessary (NN).

Employing the prescribed threshold i.e. effect size > 0.1 (Dul 2016c; Lasrado et al. 2016), 3 necessary conditions along with their level necessary for ITIL maturity are identified; SS, SSM, and Time. The next logical step is to reflect on the findings. For example, one can infer that at least one ITILV2 Service Support process (SS) must be implemented for an organization to be at a maturity level of 3.4, while at least 2 processes (SS) are necessary for maturity level 4. Further, by combining all the single necessary conditions, one can infer that to achieve high maturity (i.e. level 4 and 5), it is necessary for an organization to implement at least two Service Support processes (SS) with a process maturity of 2.1. In addition, it is also necessary that time since adoption of ITILV2 should be at least 2 to 5 years.

Furthermore, during the process of identifying necessary conditions, a closer examination of X-Y plots indicated presence of two sufficient conditions. A sufficient condition mirrors a necessary condition and by definition “ensures the existence of the outcome; i.e. if X=1 then Y=1” (Lasrado et al. 2016; Ragin 2008b). In this analysis, funding and organizational challenges were found to be almost sufficient of ITIL maturity. Hence, NCA is employed by reversing the direction of analysis i.e. challenges as Y and ITIL maturity as X and bottleneck table presented in table 5.

From table 5, it is clear that higher levels of ITIL maturity is necessary for overcoming both funding and organizational challenges. For example, a maturity level of 2 is necessary to overcome at least 3 out of 7 challenges. Furthermore, it is also necessary that time since adoption of ITILV2 is 1 to 2 years before 3 or more challenges are resolved. Digging deeper, one can infer that at least level 3 of maturity is necessary for

resolving all the funding challenges while organizational challenges could be resolved at lower maturity level of 2. In other words, as time since adoption progresses and the ITIL maturity increases the number of challenges for implementation decreases. This is further investigated using FsQCA next (step 3 & 4).

Table 5: Bottleneck Table: ITIL(Y) vs. Conditions(X).

All 7 challenges			3 Funding Challenges			4 Organisational Challenges		
Challenges	ITIL	Time	FUND	ITIL	Time	ORG	ITIL	Time
0	NN	NN	0	NN	NA	0	NN	NN
0.7	NN	NN	0.3	NN	NA	0.4	NN	NN
1.4	NN	NN	0.6	NN	NA	0.8	NN	NN
2.1	NN	NN	0.9	NN	NA	1.2	2	NN
2.8	NN	NN	1.2	NN	NA	1.6	2	NN
3.5	2	2	1.5	NN	NA	2	2	NN
4.2	2	2	1.8	NN	NA	2.4	2	2
4.9	2	2	2.1	3	NA	2.8	2	2
5.6	3	3	2.4	3	NA	3.2	2	2
6.3	3	3	2.7	3	NA	3.6	2	2
7	3	3	3	3	NA	4	2	2
Effect Size	0.286	0.286		0.167	NA		0.188	0.167
Ceiling Line	CE-FDH	CE-FDH		CE-FDH	NA		CE-FDH	CE-FDH

ITIL: ITIL Maturity; NA: Not Applicable because it is Not Necessary (NN).

V.4.2 Fuzzy-set Qualitative Comparative Analysis (FsQCA): Maturity Configurations

According to Lasrado et al. (2016), step 3 & 4 involve formulation of maturity levels, calibration of levels and conditions as well as sufficiency analysis by employing Fuzzy-set Qualitative Comparative Analysis (FsQCA). The formulation of maturity levels is designed to be an iterative process (figure 1) performed along with calibration set memberships. Lasrado et al. (2016) recommends three strategies to select maturity boundaries; “(i) boundaries are drawn at equal intervals depending on the scale used to measure maturity (in this study it is 5-point likert i.e. 1, 2, 3, 4, and 5), (ii) use the NCA results to propose stage boundaries, and (iii) draw the maturity boundaries against a benchmark, wherein the benchmarks are supported by theoretical or empirical arguments. In this paper the primary interest comparing with original research. Hence, the third strategy is employed and maturity level boundaries are set at Initial (1), Defined (3) and Optimized (5). These maturity boundaries also coincide with the ones proposed using the NCA results (see table 4).

Next (step 4), following the calibration guidelines for QCA (Fiss 2011; Ragin 2008a; Thiem 2014), this study employs that direct method of logistic transformation. FsQCA literature provides many membership functions. For example, linear, trapezoidal, logistic, triangular and many more (Thiem and Dusa 2012). In this paper, the logistic function is employed. The rationale for choosing logistic transformation (also known as log-odds method) follows the argument by Lasrado et al. (2016) that currently most of studies published (using FsQCA) employ logistic transformation over linear, triangular or trapezoidal options, especially dealing with survey data. E.g. Fiss (2011), Yi et al. (2011), Tóth et al. (2015), etc.

First the outcome (Y) is calibrated. As the outcome of interest (ITIL maturity) is divided into three sets (i.e. maturity levels of Initial, Defined and Optimized), the fuzzy set calibration is done following the approach by Fiss (2011). First, fuzzy set measures of the maturity level “Defined” is generated. For this, the membership in of organisations with ITIL maturity of 2 and below is coded 0 (full non-membership), ITIL maturity of 4 and above is coded as 1 (full membership), and finally, the crossover point is set at 3 (maturity level of 3 or Defined). Similarly, for the second set measure i.e. Optimized; the membership of maturity level of below 3 (or Defined) is coded as 0 (full non-membership), the crossover point is set at 4, and finally, the full membership is set at 5. This means that to be in the “Optimized” set, an organization

should have at least crossed level 4 and ideally be in maturity level 5. In line with prior research (Fiss 2011; Lasrado et al. 2016), the third set (maturity level “Initial”) is coded as the negation of the set with high maturity, with a full exclusion of 3 and a crossover point of 2.

Next the conditions (X) are calibrated. Again, in line with prior research (Fiss 2011; Tóth et al. 2015), each of the 8 conditions are calibration consistently . First, the number of ITILV2 Service Support (SS) and Service Delivery (SD) processes implemented are calibrated using 3 as the cross over point. Both SS and SD include include five processes each. Therefore, the upper boundary (full membership) was set at 5 and lower boundary (full non-membership) was set at 0. Similarly, the rest of the conditions are calibrated as illustrated in table 6.

Table 6: Calibration of ITIL Maturity (Y) and Conditions (X).

Condition (X)	Calibration Rules	
Processes Implemented (SS & SD)	If $SS \geq 5$, then 1 (full membership) If $SS \leq 0$ then 0 (full non-membership) If $SS = 3$ then 0.5 (cross-over point) Similar calibration for SD.	Higher the maturity level, greater are the numbers of implemented processes. The mid-point of the number of processes (3 out of 5) set as crossover.
Process Maturity (SSM & SDM)	If $SSM \geq 5$, then 1 (full membership) If $SSM \leq 0$ then 0 (full non-membership) If $SSM = 3$ then 0.5 (cross-over point) Similar calibration for SDM.	More the numbers of implemented processes, greater will be their maturity. The crossover is the theoretical mid-point (3) of the possible maturity score.
Business-IT Alignment (BITA)	If $BITA \geq 5$, then 1 (full membership) If $BITA \leq 1$ then 0 (full non-membership) If $BITA = 3$ then 0.5 (cross-over point)	Business-IT alignment increase with ITIL maturity. The crossover is the mid-point (3) of the alignment scale.
Challenges (FUND & ORG)	If $FUND \geq 3$, then 1 (full membership) If $FUND \leq 0$ then 0 (full non-membership)	Higher the ITIL maturity level, lower are number of challenges for implementation of ITIL. FUND and ORG are measures of

	If FUND = 2 then 0.5 (cross-over point) Similar calibration for ORG except, If ORG \geq 4, then 1 (full membership)	resolved challenges, hence the calibration logic.
Time since adoption (TIME)	If TIME \geq 4, then 1 (full membership) If TIME \leq 1 then 0 (full non-membership) If TIME = 3 then 0.5 (cross-over point)	Higher ITIL maturity levels are realised over time. 2 - 5 years (3) is set as crossover, with 6 months & less (1) set as full non-membership.

Now that set memberships for each of the conditions (X) and the outcome (Y) have been calibrated, the next step is to derive the maturity configurations and visualize them. The rest of the analysis follows the standard QCA analysis (Fiss 2011; Ragin 2008b) and the final results (FsQCA final solution) are presented using the core-periphery configuration chart (step 5) as shown in table 7. With regards to the parameters of fit for QCA, a minimum consistency score of 0.75, and minimum frequency of 2 is employed. The final QCA solution generates five configurations (D1a, D1b, D2, D3, and D4) for maturity level 3 (defined), and one configuration (O1) for highest level of ITIL maturity (level 5; optimized). Finally, absence of ITIL maturity (level 1; initial) generated five configurations (I1, I2, I3, I4, and I5). The findings clearly indicate that while there are many ways to be in a lower maturity levels, there is only one way to realise highest level of ITIL maturity (O1). However, the number of paths to this highest level are multiple as shown in table 7.

Black circles indicate presence of a condition, and circles with “X” indicate its absence. Large circles indicate core conditions; small ones indicate peripheral conditions. Blank spaces indicate “don’t care” condition, i.e. presence or absence has no significant impact (Fiss 2011 in Lasrado et al. 2016a).

Consistency: “degree to which cases correspond to the set-theoretic relationships expressed in a solution or the proportion of cases consistent with the outcome” (Fiss 2011 in Lasrado et al. 2016a)

Coverage: “proportion of cases with the outcome has been explained or how common is the cause among the cases with the outcome” (Ragin 2006 in Lasrado et al. 2016a).

Table 7: ITIL Maturity Level: Initial (1) vs. Defined (3) vs. Optimized (4).

Conditions (X)	Initial					Defined					Optimized
	I1	I2	I3	I4	I5	D1a	D1b	D2	D3	D4	O1
Processes Implemented											
Service Support (SS)			⊗		⊗	●	●	●	●	●	●
Service Design (SD)	⊗	⊗	⊗	⊗	⊗	●	●		●		●
Process Maturity											
Service Support (SSM)	⊗	⊗					●	●	●	●	●
Service Design (SDM)	⊗							●	●	●	●
Resolving Challenges											
Funding (FUND)	⊗	⊗		●	⊗			⊗			
Organisational (ORG)	⊗	⊗	⊗	⊗	⊗					●	●
Other Factors											
Alignment (BITA)	⊗				⊗	●		●	●	●	●
Time			⊗	⊗		●	●			●	●
Consistency	0.95	0.90	0.90	0.79	0.91	0.92	0.91	0.85	0.91	0.89	0.78
Raw Coverage	0.36	0.51	0.49	0.11	0.45	0.32	0.36	0.43	0.34	0.21	0.26
Unique Coverage	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.08	0.02	0.02	0.26
Overall Consistency	0.85					0.87					0.79
Overall Coverage	0.66					0.57					0.26

Since, the primary purpose of this paper is to facilitate comparison with original research, the relevant findings from table 4,5 and 7 are summarized as follows:

1. Service Support (SS) processes are implemented before Service Delivery (SD) processes. The initial levels of ITIL implementation (maturity level 1 and 2) are mostly associated with absence of SD processes (I1, I2, I3, I4, and I5), while SS processes are only absent for I3 and I5. Furthermore, implementation of Service Delivery (SD) processes increases with increasing maturity levels; three of the five configurations (D1A, D1b, and D3) show the presence of SD processes as a core condition. Moreover, as compared to initial levels of ITIL implementation (maturity level 1 and 2), the optimized level (5) shows the implementation of both SS and SD process as a necessary condition⁷⁰. Similar patterns of positive associations with ITIL maturity can be seen for maturity of the implemented processes (SSM & SDM) as well.

⁷⁰ A minimum of three Service Support (SS) processes implemented is necessary for ITIL maturity level of 3 and above.

2. The FsQCA solution indicates that lower ITIL maturity level (Initial) is associated with increased number of challenges for implementation. The absence of resolving organizational challenges is associated with all five low ITIL maturity (Initial) configurations, and its presence is a core condition for highest level of ITIL maturity (Optimized). Resolving funding challenges is however a “don’t care situation⁷¹” for higher levels of maturity (i.e. level 3 and above). Therefore, it can be concluded that the association of ITIL maturity and decreasing challenges is stronger for organizational challenges than the funding ones.
3. Third, a high degree of alignment i.e. managed process of alignment (4) or complete alignment (5) is necessary to realise highest level of ITIL maturity. The patterns of association are very similar to SS processes implemented; wherein initial levels of ITIL maturity are weakly associated with absence of business-IT alignment (only I3 and I4) while higher levels (defined) are strongly associated with business-IT alignment (D1A, D2, D3, and D4). Therefore, it can be concluded that business-IT alignment has a strong positive association with ITIL maturity.
4. Finally, time since adoption also showcases patterns of association similar to business-IT alignment. While its absence (less than 2 years) is only associated with lower levels of maturity (I2 and I3), its presence (more than 2 years) is necessary for highest level of maturity (optimized). Moreover, presence of time (more than 2 years) is the core condition in three of the configurations (D1a, D1b, and D4) associated with maturity level 3 (defined). Therefore, it can be concluded that higher ITIL maturity levels are mostly associated with organisations that have adopted ITILV2 for two years or more.

Now that the maturity configurations are derived, the next step (step 6) as prescribed by Lasrado et al. (2016) is to operationalize the results into a maturity measurement instrument. Since the main purpose of this paper is comparison with original research, step 6 is skipped.

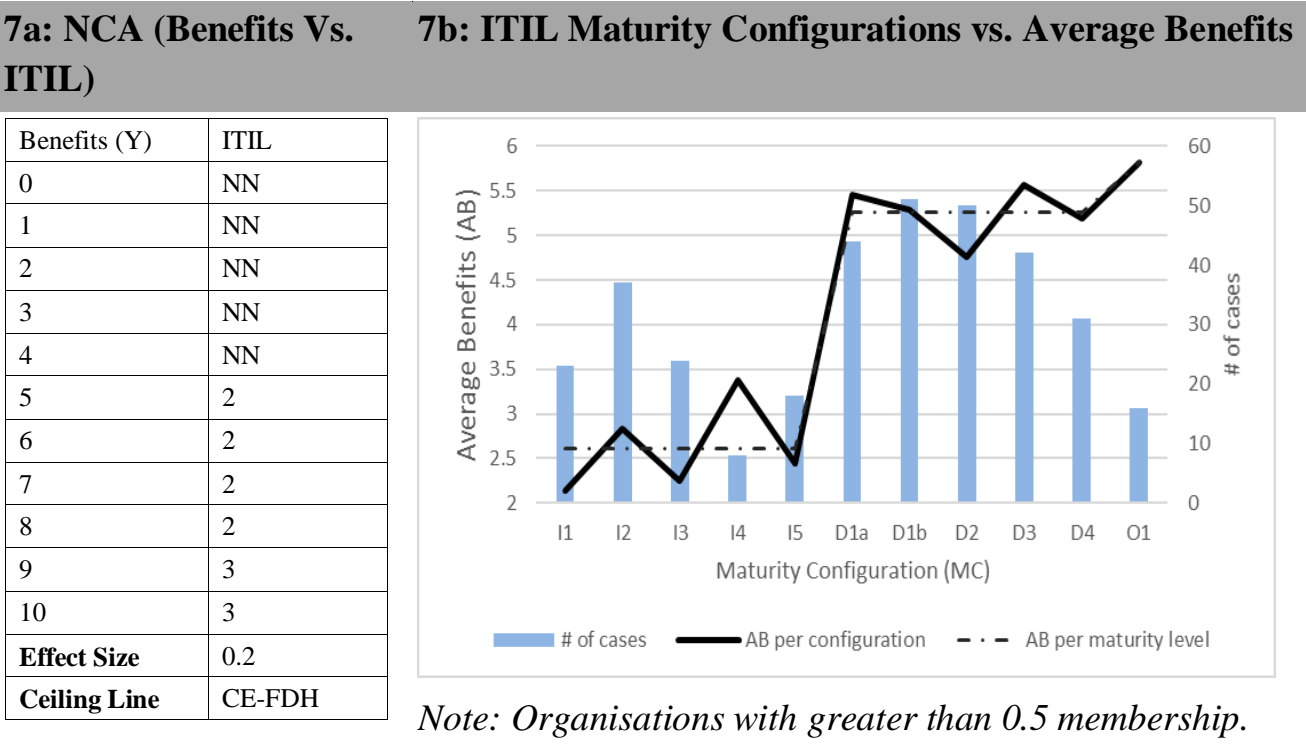
V.4.3 Business Benefits and Maturity Configurations

In this section, the association between maturity configurations (table 7) and business benefits realized (step 7) is tested. The assumption is that of higher levels of ITIL maturity would translate into increased business benefits for an organisation. First,

⁷¹ Presence or absence has no significant impact on the outcome; as the crossover point is set 2 (2 out of 3 funding barriers), this finding indicates that the perception of funding barriers remains irrespective of level of maturity.

NCA is employed with a number of business benefits as outcome (Y) and ITIL maturity level as condition (X). As illustrated in table 7a ITIL maturity is a necessary condition for business benefits, with at least a level 2 being necessary for realizing 5 out of 10 benefits (50%) listed. Similarly, maturity level 3 is necessary for realizing 90% of the business benefits. Next, average benefits realized for each of the maturity configurations are calculated (table 7b). Table 7b shows a positive association between ITIL maturity and business benefits. On an average, an increase of 102% in business benefits realized (2.6 to 5.25) is noticed between lower levels of ITIL maturity configurations (Initial: I1, I2, I3, I4, and I5) and the next levels (Defined: D1a, D1b, D2, D3 and D4). However, this increase in average number of realized benefits (5.25 to 5.81) is only minimal (11%) between the Defined (3) and the Optimized (5) maturity configurations. Based on the findings presented above, it can be concluded that as organisations mature that they realize more business benefits over time.

Table 7: Configurations and Benefits: Is ITIL maturity necessary for higher benefits?



V.5 Discussion and Conclusion

This replication study fully corroborates three of the four the findings from the original research by Marrone and Kolbe (2011a) and Marrone and Kolbe (2011b) as illustrated in table 8. In addition, this study also unveils and extends the understanding of ITIL V2 maturity (e.g. time, process maturity).

Table 8: Comparison between Original and Replication Research.

	Original Research	Replication Research
Dataset used	248 respondents for ITILV2	229 respondents, as the data is cleaned further.
Meta-Theory	Variance theory perspective	Configuration theory perspective
Methods Employed	Only Univariate methods (one X vs. one Y)	Both single condition (NCA) and multi-condition analysis (FsQCA).
Methodological difference	Correlational approach. Exploring linear and symmetric associations using law of averages.	Set-theoretic approach. Multi-dimensional Associations beyond linearity assumptions, aggregate effects, and unicausal reduction; asymmetrical associations using set relations.
Propositions Supported	All 4 propositions supported (P1, P2, P3, and P4).	3 propositions fully supported, except for one (challenges) which is partially supported.

By moving beyond the limitations of single condition analysis (employed in the original study), this replication study provides a holistic understanding of progression towards ITIL maturity. The maturity configurations (table 7) indicate towards the notion of “equifinality” i.e., not all organisations mature similarly. For example, an organization could be associated with any of 5 configurations (D1A, D1B, D2, D3, and D4) to be in maturity level 3 (Defined) but can only be associated with one configuration (O1) at the highest level of maturity(5). This clearly extends the understanding of relationship between ITIL maturity levels and the conditions as compared to the original study. For example, Marrone and Kolbe (2011a) state that “as more processes of ITIL are implemented, the perceived maturity of the ITIL implementation increases”. They also state that IT executives will not implement all processes at once but rather do them incrementally by probably hand picking the processes. However, through this replication study, using the same dataset, one can establish that IT executives will most probably implement Service Support (SS) processes first and then start implementing the Service Delivery (SD) ones. In fact, IT executives will definitely not implement more than two of the five Service Delivery

(SD) before they progress to ITIL maturity level of 3 (Defined). Another example is the relationship between business-IT alignment (BITA) and ITIL maturity. Marrone and Kolbe (2011) shows that the greatest increase in BITA is seen in the later stages of maturity, Level 3 (Defined) and Level 5 (Optimized). While this proposition is fully supported by the current replication analysis as (i) BITA is necessary for ITIL maturity level 5, and (ii) FsQCA results (table 7) indicate that lower levels of ITIL maturity does not necessarily mean low business-IT alignment. This finding definitely has managerial implications; IT executives might have achieved high levels of business-IT alignment even before realizing higher levels of ITIL maturity and subsequent benefits from its implementation. Similarly, the current study fully supports the proposition regarding business benefits and ITIL maturity levels.

However, this study only partially supports the proposition regarding ITIL maturity and decreasing challenges for ITIL implementation. First, looking at the organizational challenges (table 7), one can clearly establish a difference between maturity levels of Initial (1) and Optimized (5). Moreover, most of the maturity configurations (except D4) for Defined (3) are associated with a “don’t care situation” for organizational challenges. Therefore, one can establish a positive association between progression in ITIL maturity and decreasing organizational challenges. This is in line with the original study. However, with regards to resolving funding challenges, this replication study finds no strong evidence to support the proposition that higher ITIL maturity levels result in decreasing funding challenges for ITIL implementation. For example, while absence of resolved funding challenges are somewhat associated with Initial (1) levels of ITIL maturity, for all higher levels of maturity (i.e. level 3 and above) this condition is a “don’t care situation⁷²”. One can thus infer that while some funding challenges are resolved at lower levels of ITIL implementation, the perception of challenges associated with funding barriers will remain even at the highest levels (Optimized). Finally, this replication study also models additional conditions like time since adoption and process maturity. As expected, both time and process maturity have a positive association with ITIL maturity.

In addition, there were a few lessons learned about conducting replication studies. First, this study clearly differentiates itself from the 13 existing papers published in AIS Transactions on Replication Research by using the original dataset itself. The author(s) of this replication study contacted the original authors informally at an IS

⁷² Presence or absence has no significant impact on the outcome; as the crossover point is set 2 (2 out of 3 funding barriers), this finding indicates that the perception of funding barriers remains irrespective of level of maturity.

conference and informed them about their intent to test their original study using an alternative theoretical approach. This is consistent with the “Open Science Framework’s goal of openness, integrity, and reproducibility of scholarly research” (Dennis and Valacich 2014), which calls for open materials article sharing their materials. While the dataset was acquired through informal means, it can be considered a good example to encourage researchers in IS to share their datasets for replication. Second, the author(s) of this replication study also contacted several other maturity model researchers for their original datasets, however succeeded in acquiring only one more (i.e. success rate of less than 10%). This is slightly worrisome for replication research; the contacted authors either chose not to respond or in many cases responded stating that they had either lost their data or that they did not have access to it. One can only speculate the reasons for their unwillingness to share datasets ranging from (i) contractual obligations, (ii) fear of original analyses being questioned or even refuted, and (iii) lack of data storage practices. Whatever the reason, the author(s) of this paper concur with Dennis and Valacich (2014) regarding the importance of replication and encourage researchers to share their datasets. Finally, the dataset used is from 2009 and probably the findings may not have much practical relevance currently. Therefore, in future replications, implementation of ITILV3 could be tested and compared with the results from 2009. Although this calls for considerable effort for collection of data via surveys, it would definitely add to the growing body of ITIL academic literature and also replication research.

Survey Questions (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b)

Q1. Which of the following statements best describes your IT organization?

1. We have not adopted ITIL (Level 0).
2. We are new to ITIL and have just started to implement processes (Level 1).
3. We have a relatively low level of ITIL process maturity. Some processes are documented and these are generally understood, but errors are likely (Level 2).
4. We have a medium level of ITIL process maturity. Processes are documented monitored for compliance (Level 3).
5. We have a reasonably high level of ITIL process maturity. Our processes are documented, and measured according to established metrics (Level 4).

6. We have a very high level of ITIL process maturity. Our processes are documented, understood, backed by metrics and continually reviewed for improvement (Level 5).

Q2. Which statement would you use to describe the relationship between IT and the business?

1. Business and IT lack understanding (Level 1).
2. Business and IT have a limited understanding (Level 2).
3. There is a good understanding between IT and business (Level 3).
4. There is an improved and managed process of alignment (Level 4).
5. There is a complete alignment with integration of strategic planning of Business and IT (Level 5).

Q3. On a scale of 1–5, where 1 = No Challenge and 5 = Major Challenge, how would you rate the following barriers to ITIL implementation in your organization?

1. Lack of Executive sponsorship
2. Business understanding of ITIL objectives
3. Lack of resources (time or people)
4. Lack of internal knowledge/skills relating to ITIL
5. Lack of funding/cost of adoption
6. Organization/cultural resistance to change
7. Maintaining momentum/progress stagnates

Q4. Owing to the ITIL implementation, have you had an improvement in the following areas?

1. Service Quality
2. Customer satisfaction
3. Standardized process adoption across all of IT

4. Interaction of IT with rest of business
5. Reduction in IT downtime
6. Return on investments in IT
7. Benefited from best practice experience of others
8. Financial contribution of IT to the business
9. Call fix rate
10. Morale of IT staff

Q5. Which version of ITIL (if any) are you using?

1. ITIL V2
2. ITIL V3, upgraded from V2
3. ITIL V3
4. Have not adopted ITIL

(The following five questions are only for respondents who answered ITIL V2 on question 2)

Q5A. When (approximately) did you adopt ITIL V2

1. Over 5 years ago
2. 2 - 5 years ago
3. 1 - 2 years ago
4. Within the last year

Q5B. Which of the following ITIL V2 Service Support processes have you implemented?

1. Incident Management
2. Problem Management
3. Change Management

4. Release Management
5. Configuration Management

Q5C. Which of the following ITIL V2 Service Delivery processes have you implemented?

1. Availability Management
2. Capacity Management
3. Financial Management
4. Service Level Management
5. IT Service Continuity Management

(follow up questions for the each of processes implemented)

Q5D. On a scale of 1 - 5, how would you rate your maturity level against each of these processes implemented, where 1=Process exists but not documented and 5= Process continually improved

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Paper VI: Combining Partial Least Squares with Set Theoretic Methods: A Demonstration in the Context of Maturity Studies

Combining Partial Least Squares with Set Theoretic Methods: A Demonstration in the Context of Maturity Studies

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Abstract

This paper endeavors to contribute to the recent literature on set theoretic methods, in particular fuzzy-set QCA, by assessing whether it can be usefully combined with other correlation-based methods like PLS. Specifically, the study applies Necessary Condition Analysis (NCA), fuzzy-set QCA (FsQCA) and regression based methods (PLS-SEM) to examine the strengths and weaknesses of a combined methodological approach in understanding the conditions associated with IT service management (ITSM) maturity. The study uses a recent survey dataset studying ITSM maturity of 127 organisations. The comparison between the methods demonstrates that each has its merits and drawbacks, but combining them leads to more insightful results and findings.

Keywords: NCA, QCA, ITIL, ITSM, Maturity Models, PLS, SEM, Multi-method.

VI.1 Introduction

Although there is a common consensus that the use of multiple methods can generally achieve greater insights into the study of a particular phenomenon, the literature lacks instructive references that compare concrete different method and showcase how and under which conditions they can be combined. The methods in focus of this paper are Partial Least Squares, Qualitative Comparative Analysis and Necessary Conditions Analysis. Qualitative comparative analysis (henceforth QCA), also known as set theoretic approach (Fiss 2007; Ragin 2008a) has become increasingly prominent over the last few years in the field of political science (Thiem and Dusa 2012), business research and management research (Wagemann et al. 2016). Although developed initially by Ragin (1987) for qualitative case study researchers (medium sample size of $N < 90$), the proponents of QCA have since then argued about its unique advantages over regression-based approaches (Cooper 2005; Emmenegger et al. 2014; Wagemann and Schneider 2010) and its application for analysis of large-N datasets, in particular surveys (Cooper 2005; Emmenegger et al. 2014). The field of information systems (henceforth IS) too has seen a steady increase of its application (Dawson et al. 2016; Iannacci and Cornford 2017; Liu et al. 2017; Rivard and Lapointe 2012; Tan et al. 2016) over the last 3 years.

Furthermore, in recent discussions on QCA, many scholars (Fiss et al. 2013; Greckhamer et al. 2013; Schneider and Rohlfing 2013; Vis 2012) argue that QCA can offer better insights when applied with another approach. While methodological purists (Katz et al. 2005; Lee 2008) often argue against this (e.g. regression analysis and QCA differ epistemologically), pragmatic researchers (Fiss 2007; Fiss 2011; Levallet and Chan 2016; Vis 2012) find value in combining them and taking a multi-method approach. In fact, the most influential article applying QCA in business research (Fiss 2007; Fiss 2011), applied both QCA and statistical techniques (e.g. clustering, profile deviation analysis and regression) on a moderately large N survey. These multi-method advocates (Fiss et al. 2013; Mingers 2001; Vis 2012) argue “that the epistemological differences are an advantage rather than a drawback” and it allows for a distinct view of the problem being investigated, thus offering either complementary or contrasting insights on the same research question. We concur with these arguments and demonstrate the application of this multi-method approach on a IT service management (henceforth ITSM) dataset in this paper.

IT service management (ITSM) is a widely recognized approach among IT practitioners looking to organize IT processes and functions around customer-oriented units of delivery (Wulf et al. 2015). As both internal and external IT providers are increasingly looking to be more efficient in delivery of IT services, “the assessment of an IT provider’s service management (ITSM) maturity is becoming increasingly important and popular” (Marrone and Kolbe 2011b; Wulf et al. 2015). According to Wulf et al. (2015), the academic literature on ITSM, has only “incidentally touched upon the subject of measuring ITSM maturity”. We also found that only few existing studies have investigated the conditions associated with ITSM maturity. Moreover, most of these studies (Marrone and Kolbe 2011a; Marrone and Kolbe 2011b) have employed only single-item measures for an overall ‘ITSM maturity’ and used only statistical univariate methods (e.g. t-tests) to establish its relationship with the conditions. “Given the practical and theoretical relevance of ITSM capability for today’s IT provider organizations as well as for research” (Wulf et al. 2015), we believe there are good reasons to venture into investigating relationship between ITSM maturity and the associated conditions using multivariate methods . To this end, we use a recent dataset (Wulf et al. 2015) with a moderately large number of cases ($n = 127$) and investigate the conditions under which organizations mature with regards to ITSM capabilities. Being pragmatic researchers, we believe that this a perfect setting to contribute to the domain of both ITSM and set theoretic research.

The remainder of this working paper is structured as follows. First, we review PLS-SEM, QCA, and NCA. Second, we briefly introduce the ITSM maturity dataset in detail and explain the hypotheses to be tested (section 3). Third, we discuss the analysis steps in detail and present the results for each of the three methods. By walking through the analysis steps in detail, we also document the methodological challenges and prescribe some strategies to overcome them (section 4). Next, we combine the three results and derive our final inferences (section 5). Finally, we conclude the paper.

VI. 2 Analytical Methods Overview : PLS-SEM, QCA, and NCA

To date, quantitative research in IS has employed the use of correlation based methods, mostly multiple regression analysis (MRA) and structural equation modelling (PLS-SEM) (Liu et al. 2017). PLS-SEM combines a factor approach from a psychometric tradition with a path analytic approach from econometric tradition. PLS-SEM allow analyzing path relationships between latent variables measured by multiple items

(Levallet and Chan 2016). The underlying principle is that of linear regressions, which is used to “minimize residual variance and maximize explained variance in the dependent variables” (Chin 1998; Levallet and Chan 2016). An advantage of SEM is that both measurement and structural models are tested together in one step (Levallet and Chan 2016). PLS-SEM is the most popular SEM technique in the domain of information systems mostly due to three reasons; (i) PLS does not make normality assumptions, (ii) PLS supports complex models with a large number of indicators and (iii) although sometimes debated PLS can detect effects in very small samples (Ringle et al. 2012). In addition to this, the software “SmartPLS (Ringle et al. 2015)” has increased its popularity because of its friendly user interface, reporting features and ease of use.

QCA is a set-theoretic method that models associations as subset or superset relations in terms of necessity and sufficiency. QCA focusses on arriving at casually complex patterns in terms of equifinality, multiple conjunctural causation and asymmetry (Fiss 2007; Ragin 1987; Ragin 2008b; Wagemann and Schneider 2010). QCA is designed to compare multiple cases in terms of complex configurations of conditions and outcomes (Bedford and Sandelin 2015). The ultimate goal of QCA is to analyze set-theoretic sufficiency relations (Ragin 1987). QCA is grounded in the analysis of set relations, not correlations (Ragin 2006; Ragin 2008b) and hence unlike conventional statistical methods it does not measure the average effect of an increase or decrease of one variable on another (Bedford and Sandelin 2015). Instead, QCA analyses complex connections between attributes and outcomes in terms of set relationships” (Lasrado et al. 2016). QCA has two main types, Crisp set QCA (CsQCA) and Fuzzy set QCA (FsQCA). In CsQCA, a condition is either fully present or fully absent, whereas FsQCA is more flexible; it allows assignment of fuzzy memberships to conditions, thus expressing degree of presence and absence (Olsen and Nomura 2009). In this study we use FsQCA for our analysis.

Necessary Condition Analysis (NCA) is a technique for identifying relationships of necessity that can make both statements in kind and in degree (Dul 2016a). NCA uses Data Envelopment Analysis (DEA) based techniques. While QCA as set-theoretic method has a number of advantages in the analysis of complex causations, some scholars (Goertz 2006; Vis and Dul 2016) argue that in few cases QCA fails in identifying all necessary conditions, specially single necessary conditions. In line with recommendations by Lasrado et al. (2016), we use NCA just as a complimentary method to subvert the weakness of QCA in detecting necessary conditions.

The fundamental difference between the primary methods used in this study is their underlying principle of operation; PLS-SEM works on additive logic (similar to linear regression), while QCA works on a configurational logic. For example, in PLS-SEM, if an outcome (dependent variable) occurs and the given cause (independent variable) does not, this counts as negative evidence for the strength of that association and/or causal relationship. On the contrary, QCA identifies associations and/or causal patterns that differ across subsets of cases (presence & absence of outcome separately) allowing for more complex causal narratives to be assessed (Ragin 2008a; Vis 2012). This fundamental difference means that the type of hypotheses tested and conclusions drawn using PLS-SEM and QCA sometimes diverge (Thiem et al. 2016). Other differences exist and are briefly summarized in Table 1.

Table 1: PLS, QCA and NCA – Comparison relevant to this study (Greckhamer et al. 2013; Liu et al. 2017; Ragin 2008a; Thiem et al. 2016; Vis and Dul 2016)

Characteristic	PLS-SEM	QCA	NCA
Underlying logic	Additive logic: “single determinants are sufficient but not necessary for increasing the outcome”.	Configurational logic: Configurations are sufficient but not necessary to produce the outcome (“equifinality”).	Necessity logic: A condition is necessary but not sufficient to allow the outcome
Key Assumption	The relationships between conditions are symmetric and linear.	The relationships between conditions can be either asymmetric or symmetric	No assumptions on relationship between conditions.
Hypothesis formulation as	Positivity and Negativity whose two arguments are increase and decrease.	Sufficiency and Necessity, whose two arguments are “absence and presence”	Arguments of necessity: X is necessary for Y
Examination of relationship	p-value is used: X significantly affects Y at the level of p-	Consistency is measure for strength of sufficiency of a combination.	Emptiness of upper left corner in a X-Y plot.

	value < 0.001.		
Knowledge accumulation	Acceptance or rejection of hypothesis based on the strength of its effect & p-value	Detection of a configuration is related to its existence and coverage value.	Detection of degree of necessity. Level X necessary for Level Y.
Relationships between conditions	Conditions compete to explain the phenomena through R ² .	Conditions cooperate to explain the phenomena by means of configurations	Single condition analysis.
Analytic approach	Linear Regression	Boolean minimization	Ceiling line (Data envelopment analysis)
Suggested Sampling	Random	Purposeful or subjective	Random
Sample Size	all kind of n's.	Initially Small N (<30) or Medium N (<90). Lately have been widely applied in moderately large N studies (90 to 300).	all kind of n's.
# of conditions	Thumb rule is at least ten samples per one condition.	4 to 6 conditions for Medium N (<80), while 6 to 12 for large N.	NA

Now that we have briefly presented the overview of PLS-SEM, QCA and NCA, in the next section, we present the ITSM maturity dataset and hypotheses that will be tested using these three methods.

VI.3 Case: ITSM Maturity Dataset

For the demonstration of the proposed multi-method approach, we use a subset of the data⁷³ (N=127 organizations) used in a recent research study (Wulf et al. 2015) investigating ITSM maturity. The survey instrument used was developed and validated as part of that study (Wulf et al. 2015). This study measured the levels of the 25 common ITSM processes, based on the nomenclature and process descriptions of the widely used ITIL reference model (Wulf et al. 2015). In addition, the survey collected data of contextual factors (referred to as conditions in this paper) that are considered adequate for ITSM process maturity (e.g. IT strategy, employee capability, system criticality, etc.), which we briefly describe next along with our hypotheses for this study.

VI.3.1. Measuring Service Operations Maturity (Outcome)

ITSM Maturity, here in this study, is measured as a second-order construct that is composed of multiple first-order dimensions (4 sub-capabilities). The 4 sub-capabilities, each describing a certain phase of the Service Lifecycle: Service Strategy, Service Design, Service Transition, and Service Operation are reflected in the multi-attributive measure of maturity of their associated ITSM processes. For this method comparison study, we focus on the sub-capability Service Operation (SO) as the outcome/dependent variable⁷⁴. In short, Service Operation (Y) represents the phase at which an actual delivery of the IT service takes place. Service Operation includes the following processes: Event Management (Event Mgt), Incident Management (Inc Mgt), Request Fulfillment (Req Full), Problem Management (Prob Mgt), and Access Management (Acc Mgt) (Wulf et al. 2015). The maturity level of each of the 5 processes was measured on a multi-attributive scale using the six CMM based process assimilation stages (1: none, 2: initial, 3: repeatable, 4: defined, 5: managed, 6: optimized), each detailed out with specific descriptors. The five processes are reflective and the factor loadings exhibit values of well above 0.7 (Table 3).

⁷³ Reasoning: We had enough data for PLS-SEM for Internal service providers (N=127). Data for External service providers was very small (N=29), hence using PLS-SEM was not possible.

⁷⁴ Reasoning: Organisations that answered the survey had achieved acceptable level of maturity for Service Operation (mean 3.6), while rest 4 sub-capabilities had most of the organisations reporting initial and none (mean 2.2 to 2.5).

VI.3.2 Explanatory Conditions (X) & Hypotheses

As very few academic studies exist on ITSM despite its popularity among practitioners (Iden and Eikebrokk 2014; Marrone and Kolbe 2011a), the makers of the survey instrument (Winkler et al. 2015) rely on literature from the domain of IT strategy (Chen et al. 2010), organizational capability (Bharadwaj 2000) and maturity models (Becker et al. 2010; Paulk et al. 1993) in addition to practitioner interviews to arrive at the relevant contextual factors. In fact, as part of the introduction to their survey instrument (itil.selfsurvey.org), they state “the study is novel as a special focus is placed on the role of contextual factors (conditions) for an adequate ITIL process maturity”. With this as our background, we now briefly explain the 6 contextual factors or conditions (X) and list the hypotheses that will be tested in this study (Table 2).

Table 2: Conditions (X) and Hypotheses.

Condition (X)		Definition	# items	Hypotheses
IT Strategy	Innovator IT Strategy (INN)	Organizational perspective on investment in, deployment, use, and management of IT aimed at utilizing innovative IT initiatives for organization’s benefits.	3	H1: “is negatively associated with SO maturity”
	Conservative IT Strategy (CON)	Organizational perspective on investment in, deployment, use, management of IT aimed at creating value through optimizing and refining existing IT practices.	3	H2: “is positively associated with SO maturity”
IT Employee Capability (ITEMP)		The current level of the aggregate skills of the employees at the service provider side.	7	H3: “is positively associated with SO maturity”
System criticality (SYS)		The degree to which organization’s activities depend on an IT service.	5	H4: “is positively associated with SO maturity”

Service Provider size (SPZ)	Number of Employees at the IT service provider.	1	H5: “is positively associated with SO maturity”
Service Orientation (SER)	The degree to which an organization is the service sector.	2	H6: “is positively associated with SO maturity”

Reasoning for the Hypothesis:

H1 & H2: Winkler et al. (2015) hypothesizes that conservative IT strategy is positively associated with SO maturity, while innovator IT strategy is expected to be negatively associated with it. This is because high SO maturity is associated with high process formalization (Chen et al. 2010; Marrone and Kolbe 2011a) and the rigidity of highly formalized procedures is known to decrease innovativeness and hinder flexibility. On the contrary, organizations seeking increased efficiency would opt for more formalized procedures (Chen et al. 2010), thus seeking higher level of maturity for their IT routines, and opting for a conservative IT strategy.

H3: High level of formalization also requires a qualified workforce with specific skills and necessary certifications. In fact prior literature suggests that ITSM employees are required to continuously “learn, manage, and support complex IT systems and processes”, while simultaneously certifying themselves (Bhagwatwar et al. 2014). Moreover, the highest level of ITSM maturity requires organizations to invest in continuous improvement of skills and expertise (Wulf et al. 2015). Based on the above arguments, we hypothesize that IT employee capability is positively associated with SO maturity.

H4: IT services support day-to-day business activities and a service downtime will incur a noticeable cost impact for the business. As the ITSM maturity of an organization increases, so does the penetration of IT across all of its business activities (Marrone and Kolbe 2011a). This makes highly mature organization strongly dependent on the IT systems and the criticality of keeping it fully functional becomes paramount for its survival. In line with this argument we hypothesize that system criticality is positively associated with SO maturity.

H5 & H6: It is a well-known and documented fact that large organizations invest in high process formalization (Chen et al. 2010). With regards to literature on capability maturity model (CMM), there is well documented evidence that its success is only possible for large companies (Pino et al. 2008). Furthermore, since service businesses also have a greater internal focus on service management and value cocreation between business and IS functions (Tallon 2010). In line with this logic, we hypothesize that company size and its service orientation is positively associated with SO maturity.

In this section we have briefly explained the ITSM maturity dataset and presented our hypotheses. Next we analyze the data, describe the process followed for each of the methods and finally present the results.

VI.4 Analysis and Findings

The dataset consists of 7 constructs, composed of a total of 26 indicators or items (Table 3), varying from one to a maximum of seven. First, we examine characteristics of the data by checking for the missing data and visualizing the descriptive statistics (i.e. mean, standard deviation, measures for normality like kurtosis and skewness, etc.) In our data, there were no missing data and most of the indicators had a reasonable degree of normality (kurtosis $\leq |1.0|$, skewness $\leq |0.70|$) except for the following indicators: i) 4 measures of system criticality exhibited kurtosis and skewness, with a long tail towards the upper end of the tail. ii) One measure of service orientation (PhysVsInform) and one measure of innovation strategy (Inn 1) also exhibited some kurtosis. Table 3 displays the descriptive statistics for all indicators.

VI.4.1 PLS-SEM Analysis

We use the SmartPLS 3.2 software (Ringle et al. 2015) to estimate and evaluate the path model, using the path weighting scheme. We follow recommendations by Hair et al. (2011) and evaluate the PLS estimates for the overall model (table 4). Following best practice in PLS-SEM (Hair et al. 2011; Jetzek et al. 2013), in addition to the evaluation of R^2 values the predictive relevance of the model is assessed through blindfolding procedures to obtain cross-validity redundancy measures for each

construct. The results indicate a good predictive relevance of the model with all Q^2 are well above zero (Hair et al. 2011)⁷⁵.

Furthermore, all the indicators loaded on their respective constructs (Table 3) with most reflective factor loadings exhibiting values of well suggested threshold value of 0.7 (Hair et al. 2011). Average variance extracted (AVE) of all reflective measures is clearly above the recommended level of 0.5 confirming convergent validity (Hulland 1999). Composite reliability is also good too with values above 0.8 and internal consistency (Cronbach's Alpha) is in all cases, except one (conservative IT strategy) above the recommended threshold of 0.7 (Hair et al. 2011). However, since the Cronbach's Alpha for conservative IT strategy is just below the threshold (0.691) and it satisfies all other validity and reliability measures, we consider it adequate for further analysis.

Before, we proceed any further with the analysis, we check if there is a possibility to reduce the number of conditions without losing the predictive relevance of the model. However, the problem of deciding which of the 6 conditions to include in the final model manually is arguably the hardest part (Lumley and Miller 2009; Yang 2013). In order to complete this task we use the prescribed automated approach⁷⁶ (Yang 2013). This approach selects a subset from the pool of independent variables "that gives adequate prediction accuracy for a reasonable cost of measurement" (Yang 2013). It considers all possible subsets of the pool of explanatory variables and finds the model that best fits the data according to defined information criteria (e.g. Adjusted R², AIC and BIC). Following the prescribed guidelines (Lumley and Miller 2009; Yang 2013), we arrive at 3 best models. We then estimate and evaluate all models and compare the results with each other. In addition to PLS estimates explained earlier, we also use the SRMR fit indices⁷⁷ (Hu and Bentler 1999). The results are compiled in table 4.

Table 4 gives us a many good reasons to select model 1. Firstly, this model was the default chosen based on the AIC measures. Secondly, the R sq. of 0.339 is the best among the three models, and all other fit indices are within acceptable prescribed limits. Third, we do not see drastic reduction in accuracy (Avg. RMSE) as we reduce the number of variables. Finally, just comparing the level of significance, Model 1 facilitates testing for 5 of the 6 hypotheses.

⁷⁵ Blindfolding procedure was calculated for omission distance $d=7$ and the results are in table 4. There is no multicollinearity between the 6 variables, as the VIF scores are between 1.04 and 2.3.

⁷⁶ We use the "Leaps" R package (Lumley and Miller 2009)

⁷⁷ For a model that fits the data, the SRMR would be "close to" 0.09 or lower (Hu & Bentler 1999)

Table 4: PLS-SEM results.

	Model 1	Model 2	Model 3
System Criticality	0.161*		
IT employees Capability	0.235***	0.290***	0.269***
Innovative IT Strategy	-0.174	-0.162	
Conservative IT Strategy	0.311***	0.314***	0.262***
SP Size	0.242***	0.286***	0.257***
Product Vs. Service Type	-0.170**	-0.151*	-0.145*
Org Client Size			
R sq.	0.339	0.321	0.298
Q²	0.181	0.172	0.164
SRMR Composite Factor	0.069	0.062	0.062

*p<0.1, **p<0.05, ***p<0.01

Based on PLS-SEM analysis, we thus confirm our hypothesis that IT employees Capability is positively associated with SO Maturity with a moderate effect⁷⁸. We also confirm that Conservative IT Strategy, and Service Provider Size are positively associated with SO Maturity with a small effect. Hypothesis on system criticality was also confirmed, but at 0.1 level of significance. However, contradicting our hypothesis service companies were found to be negatively associated with SO Maturity at 0.05 level of significance. Finally, while we find a negative association between innovator IT strategy and SO maturity, the results are found to be not significant.

⁷⁸ In line with commonly accepted thresholds (Cohen 1988), we state the hypotheses results with path coefficients β greater than or equal to 0.5, 0.3, and 0.1 as large, moderate, and small effects, respectively.

VI.4.2 QCA and NCA Analysis

VI.4.2.1 Calibration of PLS-SEM Factor Scores into Fuzzy Sets

We follow the six step procedure of applying set theoretical approach to maturity models (Lasrado et al. 2016). The only difference from the procedure is that we first transform the PLS-SEM factor scores into fuzzy-set memberships and then apply Necessary condition analysis. We do so to maintain consistency and facilitate comparison with PLS-SEM results. For calibrating fuzzy-sets, “the researcher establishes when a case is ‘fully in’ a set (1), ‘fully out’ of it (0) and when it is ‘neither in nor out’ of the set (the so-called cross-over point) (.5) using external criteria, in particular theoretical and/or case knowledge” (Ragin 2008a; Thiem and Dusa 2012; Vis and Dul 2016). We employ the direct calibration process (Ragin 2008a) and following the work of Fiss (2011), Levallet and Chan (2016) and many others use the mean of PLS factor scores (i.e. 0) as the midpoint or cross-over point. The “fully out” set membership criteria is set at 25th percentile and “fully in” membership is coded at 75th Percentile. Furthermore, a simple linear transformation with entry into set membership as minimum of the PLS scores and full membership coded as maximum of the PLS scores is also calculated. This is done to identify single necessary conditions using NCA in accordance with recommendations by Dul (2016a)⁷⁹.

VI.4.2.2 Necessary Condition Analysis

Next, NCA is employed on the dataset. We do so by first examining the NCA graphs (X-Y plots) and then evaluating the effect size. Effect size is the measure of the area of emptiness in the top right corner of the X-Y plot and is calculated by drawing ceiling lines enveloping the data. Various techniques and reasoning for using them are prescribed in the R package (Dul 2016b) for NCA. “Depending on how the condition is measured (i.e. discrete or continuous) and the interpretability of the results, the appropriate type of ceiling line (i.e. CE-FDH, CR-FDH or any other) is selected⁸⁰. Finally, the level of conditions (X) that are necessary are listed against the outcome (i.e. level of maturity) as shown in figure 5 and reflected upon in a tabular format”

⁷⁹ “NCA results with logistic transformed data and those with standardized transformed data differ substantially. Hence Dul (2016a) recommends using the linear transformation, so that the fuzzy sets are a 100% translation of the original raw dataset.

⁸⁰ A piecewise linear ceiling with free disposal hull technique (CE-FDH) and a ceiling regression with free disposal hull technique (CR-FDH) is suggested for discrete and continuous data respectively (Dul 2016c).

(Lasrado et al. 2016)⁸¹. Dul (2016c) suggests to use effect size of 0.1 as the threshold. However, based on recent studies using NCA (Lasrado et al. 2016), we believe that examining X-Y plots and the bottleneck table yield necessary conditions with special conditions also with an effect size less than 0.1. Furthermore, a recent paper (Vis and Dul 2016) proposes multivariate NCA, wherein the individual necessary conditions can be combined into necessary AND configurations.

We follow the prescribed NCA guidelines (Dul 2016c), and identify 4 single necessary conditions as highlighted in table 5. Conservative IT strategy, SP Size, System Criticality and IT employment capability were all identified as single necessary conditions. However, on closely examining the degree of necessity (bottleneck table), we observe that only an above average presence (i.e. membership value of 0.5 and above) of conservative IT strategy, system criticality and IT employment capability is required only to achieve very high maturity (i.e. membership value of 0.89 and above). Furthermore, combining System Criticality and IT employment capability as AND combinations (Vis and Dul 2016), we conclude that for very high maturity (0.89 and above), System Criticality and IT employment capability are both necessary.

Table 5: Bottleneck Table; Shaded values indicate degree of necessity above membership of 0.5

Y (SO)	CON	INN	SPS	SER	SYS	EMP	~INN	~SER	AMBI
0	NN	NN	NN	NN	NN	NN	NN	NN	NN
0.056	NN	NN	NN	NN	NN	NN	NN	NN	NN
0.167	NN	NN	0.003	NN	NN	NN	NN	NN	NN
0.222	NN	NN	0.029	NN	0.038	NN	NN	NN	NN
0.333	NN	NN	0.08	NN	0.115	NN	NN	NN	NN
0.444	NN	NN	0.131	NN	0.191	0.104	NN	NN	NN
0.5	NN	NN	0.157	NN	0.23	0.165	NN	NN	NN
0.611	0.101	NN	0.208	0.013	0.306	0.289	0	NN	NN
0.667	0.182	NN	0.234	0.021	0.345	0.35	0.006	NN	NN

⁸¹ The tabular format is referred to as the bottleneck table (Dul 2016c).

0.778	0.344	NN	0.285	0.038	0.421	0.474	0.017	NN	NN
0.889	0.507	0.353	0.336	0.054	0.498	0.597	0.029	NN	0.33
0.944	0.588	0.621	0.362	0.062	0.536	0.658	0.034	0.312	0.568
1	0.669	0.888	0.388	0.07	0.574	0.72	0.04	0.63	0.806
Effect Size	0.153	0.082	0.163	0.017	0.239	0.234	0.008	0.035	0.076
Ceiling Line	CR-FDH	CR-FDH	CR-FDH	CR-FDH	CR-FDH	CR-FDH	CR-FDH	CR-FDH	CR-FDH
Accuracy	96.90%	97.60%	98.40%	100%	95.30%	92.90%	100%	100%	96.90%

NN: Not Necessary; CR-FDH: Ceiling line using regression with free disposal hull technique.

Now that all the necessary conditions with effect size greater than 0.1 are identified, we look at the ones with small effect (less than 0.1). We first examine innovation strategy (INN). From the bottleneck table, it is evident that innovation strategy (INN) is only necessary for maturity of 0.92 and above. From our initial hypothesis, innovation strategy (INN) is understood to be negatively associated with SO maturity. Therefore, we negate the innovation strategy fuzzy set score (\sim INN) in order to explore if its absence is necessary for maturity. We find that \sim INN is not necessary for maturity. Next, we test AND configurations (Vis and Dul 2016) by combining innovative and conservative IT strategy (also known as ambidextrous, AMBI). We find that ambidextrous strategy (membership value of 0.568) is necessary for very high maturity (maturity of 0.944). Next, we test necessary relationship between undefined strategy and below average maturity (\sim SO). We do so by combining negation of innovative (\sim INN) and negation of conservative IT strategy (\sim CON) and find no “necessary” relationship between undefined strategy and below average maturity. Finally, we negate the fuzzy score for service orientation (\sim SER). Although the effect size is very small (0.035), it is significantly higher than that for its presence (SER). This finding provides some evidence that being a product company is actually necessary for maturity of greater than 0.97⁸². The results and interpretation of NCA results are also compiled in table 7 and compared with the PLS-SEM results.

⁸² As compared with Service orientation (SER), the effect size for \sim SER increases from almost 0 to 0.035.

VI.4.2.3 Qualitative Comparative Analysis (QCA)

Now that we have identified the necessary conditions using NCA, the next step is to facilitate the extraction of configurations for SO maturity using QCA. QCA sufficiency analysis is a well-established method with prescribed guidelines (Lasrado et al. 2016) and involves calibration of data into set memberships, formulating the truth table, Boolean minimization, counterfactual analysis, and finally arriving at the most parsimonious and intermediate solutions (Wagemann and Schneider 2010). Proponents of QCA (Cooper 2005; Ragin 2008b) also require the researcher to test for presence for necessary conditions before starting the QCA analysis. Therefore, using the prescribed threshold of consistency = 0.9 and coverage = 0.5 (Wagemann and Schneider 2010) we test for presence for necessary conditions using the QCAPro R package (Thiem 2016). We do not find any single necessary conditions⁸³ explaining the presence of above average SO maturity.

After calibrating the fuzzy set scores using QCAPro for calibration (section 4.2.1), we used fs/QCA software program (Ragin and Davey 2014) to find the configurations of conditions associated with the presence (i.e. above average maturity) and absence (i.e. below average maturity). In line with accepted practice (Wagemann and Schneider 2010), we first set a minimum inclusion criteria of 0.8⁸⁴ and frequency threshold of 2 cases⁸⁵ per configuration to be included in our analysis. Next step in the analysis is logical minimization to determine the commonalities between configurations that consistently lead to the outcome (Fiss 2011; Ragin 2008b). We followed the prescribed steps (Ragin 2006; Ragin and Davey 2014; Thiem and Dusa 2012) to arrive at the final solution. The directional expectations or counterfactuals (Thiem and Dusa 2012) for system criticality, IT employee capability, conservation strategy and service provider size are coded as present, as these conditions (X) are expected to be present for above average SO maturity. However, innovative strategy and service orientation are coded as absent, as they are expected to be absent. It is an easy counterfactual as the decision is based on prior case knowledge⁸⁶. Similarly, system criticality, IT employee

⁸³ As discussed in section 4.2.1, data used here is calibrated using Fiss's quartile logic (logistic function).

⁸⁴ Ragin (2008) suggested a minimum of 0.75. However, in the absence of definitive consensus, we tested the QCA results using both 0.75 and 0.8.

⁸⁵ Fiss (2011) used a frequency threshold of 3. However, in our case by using N=3, we use only 68% of the dataset as compared to 86% with N= 2. Moreover, the number of rows in the truth table reduce to 21 from 32 causing couple of the interesting configurations (with low coverage) to be lost.

⁸⁶ Prior case knowledge is based on the PLS-SEM and NCA findings. Since we use the PLS factor scores for calibrating the fuzzy sets, the results from PLS are considered as strong knowledge to code these counterfactuals.

capability, conservation strategy, innovation strategy⁸⁷ and service provider size are coded as absent for below average SO maturity. However, in the absence of strong prior evidence regarding service companies and below average maturity, we coded the counterfactual as present or absent. With regards to the parameters of fit⁸⁸ for FsQCA, prior literature suggests that the minimum consistency score should be at least set at 0.75, and there is no minimum requirement for coverage⁸⁹ in literature (Bedford and Sandelin 2015; Rivard and Lapointe 2012). Furthermore, following QCA robustness methodology, we concur with Wagemann and Schneider (2010)'s idea of robustness that "QCA solution is robust if it involves similar necessary and sufficient conditions across different model specifications⁹⁰ and are in a clear subset relation and parameters of fit do not warrant different substantive interpretations". In line with prior recommendations by QCA scholars (Skaaning 2011; Wagemann and Schneider 2010), we assess the sensitivity of QCA solutions with different threshold frequency (N=2, and 3) and minimum inclusion criteria (0.75 and 0.8)⁹¹. Applying the described process, we arrive at multiple QCA solutions satisfying all the parameters of fit and the results are presented in table 6. Finally, since the audience for maturity models is usually management oriented we use the Core-Periphery Configuration Chart (Fiss 2011) for presenting the results. The Core-Periphery Configuration Chart is preferred due its visual symmetry with prior maturity models and ease of understanding for non-experts who are not familiar with boolean expressions.

Now that we have the QCA solutions (also referred as different model specifications), we look at empirical cases that explain these different configurations. Using best practice in the field (Emmenegger et al. 2014; Legewie 2013; Rumble and Mangematin 2015) as benchmark, rather than examining every case, we focused on those cases that contradicted or deviated from the configuration⁹². In case of large or medium N surveys, it is practically not possible to have in-depth case knowledge of the deviant cases. In the absence of practical guidelines, we convert the number of deviant cases or

⁸⁷ Innovation strategy was coded as absent. This is because according to our hypothesis "undefined strategy" is associated negatively with SO maturity. By definition undefined is "absence of conservative and innovative strategy".

⁸⁸ Refer (Thiem and Dusa 2012) page 69-73 for prescribed tests and formulae.

⁸⁹ Fiss (2011), and few others consider a overall coverage of 0.35 and above as substantial. However, there is no consensus on what the minimum number should be.

⁹⁰ The term "different model specifications" refers to QCA solutions with different combinations of threshold frequency and minimum inclusion criteria. In total we have 4 such combinations (table 6)

⁹¹ We looked at the effects of changing calibration by (1) changing the "fully in" and "fully out" values and (2) checking impact of using fuzzy linear function vs. the prescribed logistic one (table 6).

⁹² We also looked at borderline cases i.e. with between membership of 0.51 and 0.55.

contradictions to create a measure of error⁹³. Comparing the different model specifications, we conclude that the QCA solution presented in table 6 is robust. Furthermore, by comparing the different configurations (table 6), we extract clear patterns that explain both above and below average maturity. We then compare the findings with that of PLS-SEM and NCA.

VI.5 Towards Combining PLS, QCA and NCA

We compile the results from the three methods (see Table 7) and discuss our triangulated findings. In order to avoid repetition, we make an effort to guide the reader through the analysis⁹⁴. We apply the principles of methodological triangulation (Jack and Raturi 2006; Mingers 2001; Mingers and Brocklesby 1997) under the assumption that these three methods complement each other and the “weaknesses inherent in one approach will be counter balanced via strengths in another”. From Table 7, we can clearly establish a strong association between System Criticality and SO maturity. Both PLS-SEM and QCA results support the above statement. In fact, system criticality is present in all the three configurations (2a, 2b, 2c) associated with above average maturity. In addition to this, NCA establishes system criticality to be necessary for very high maturity i.e. the absence of it guarantees not realizing very high maturity. Therefore, we state that system criticality is likely the most important characteristic of companies that have high SO maturity.

For IT strategy, we find strong positive association between conservative IT strategy and SO maturity. Strongly corroborating the results from PLS-SEM, we find that two QCA configurations (2a and 2c) explaining 39% of the above average maturity cases, associating themselves with presence of conservative IT strategy, while two other configurations (1a and 1b) explaining 27% of the below average maturity cases associate themselves with its absence. In addition to this, NCA also establishes that conservative IT strategy to be necessary for very high maturity. With regards to Innovator strategy, while its absence establishes a strong association with above average SO maturity, we find divergent associations with regards to below average and very high maturity. Firstly, we find some evidence (from NCA), that while innovation strategy in general and ambidextrous strategy in particular could be necessary for very

⁹³ The purpose of this % error measure is to compare different QCA solutions. The logic is simple: “smaller the error better is the solution”.

⁹⁴ This is a first such attempt to collate and present triangulated findings using PLS, QCA and NCA. In the absence of an already established standard, some of the interpretations are explained in the table.

high maturity, we also find that only having an ambidextrous strategy is not sufficient for even above average maturity (configuration 1c). While presenting our results, we argue for so-called dissonance from methodological triangulation (Jack and Raturi 2006) and conclude that while Innovator IT strategy is negatively associated with maturity, it is only up to a certain level. Ambidextrous IT strategy could be necessary for very high maturity, provided system criticality and IT employee capability are in place. We carefully choose the words “could be” as we did not have strong corroborating evidence from either QCA and NCA for very high maturity. Finally, we argue for the other three conditions i.e. (i) service provider size, (ii) its service orientation, (iii) IT employee capability and present the results in Table 8.

Table 8: New Insights to ITSM Maturity research.

	Hypotheses	PLS-SEM	NCA QCA	Examples of additional insights using multi-method approach.
1.	System criticality is associated positively with SO maturity.	✓	●	Highly mature companies rely heavily on IT services, and criticality of keeping it fully functional is highly important. QCA extracts this pattern and identifies system criticality as both necessary and sufficient for above average maturity, hence making it a very important condition.
2.	IT employee capability is associated positively with SO maturity.	✓	●	Yes, IT employee capability is associated positively with SO maturity and is necessary for very high maturity.
3.	The innovator IT strategy is associated negatively with SO maturity.	-	●	Yes, Innovator IT strategy is negatively associated with SO maturity, but only to a certain level. Innovator IT strategy could be necessary for very high service operations maturity. In fact, both Conservative IT and Innovative strategy could be
4.	The conservative IT strategy is associated positively with SO maturity.	✓	●	simultaneously (ambidextrous) necessary for very high maturity, provided system criticality and IT employee capability are in place.

5.	SP size is positively associated with SO maturity.	✓	●	While larger service providers are associated with higher SO maturity, there exist multiple configurations of SO maturity, wherein size does not matter. There is in fact a stronger association of smaller SP size and below average maturity.
6.	Services Companies are expected to be more mature than product companies.	X	●	No, Service companies are not more mature than product ones. In fact, being a product company might actually be necessary for very high maturity.
✓ Hypothesis found to be true; X Evidence contradicting prior hypothesis/assumptions; - No Conclusions ● Fully supports PLS findings; ● Supports PLS findings to a large degree; ○ Supports PLS findings to a small degree;				

As stated earlier, we do not aim to prove causation, but seek to demonstrate association between SO maturity and the six conditions. Furthermore, our primary aim with this paper was to demonstrate a positive use case for researchers wanting to take a multi method research approach. In sum, in this section, we have been successful in achieving both these goals. In addition, we have presented many additional insights regarding SO maturity which was only possible using a multi-method approach. Furthermore, unlike PLS-SEM and NCA, as QCA also identifies the cases that explains and contradicts the final solution. One could fully study these cases and derive deeper insights. However, providing an account of these cases is not within the scope of this paper.

VI.6 Conclusion

Through this paper we have shown that a multimethod approach of combining QCA, NCA and PLS-SEM is valuable in the context of ITSM maturity. In doing so, we tried to contribute to a recent call for combination of configurational approaches with traditional statistical techniques. The combination of the three methods in this study has shown that both QCA and NCA prove a valuable addition to PLS-SEM, as some important results would have remained hidden with only PLS-SEM analysis. For

example, we found that innovator IT strategy has a negative bearing on SO maturity; however, the relationship was found to be not significant (p-value). If we adhere with only to PLS-SEM, then the only practical way to establish a significant relationship was by collecting more data. However, by using QCA we compensate for this and establish that innovator IT strategy is absent in majority of the configurations and thus negatively associated with above average maturity. Similarly, we were able to provide the ITSM community with few newer and interesting findings (table 8) and thus contribute to the growing domain of ITSM⁹⁵. Furthermore, through this paper we have provided a template that researchers could use to present the combined findings.

In this paper, while we demonstrate that combining PLS-SEM, NCA and QCA provides valuable insights, we acknowledge that the findings are preliminary and need further validation. One major limitation of this paper is that we have used QCA configurations and the measures of fit (i.e. consistency and coverage) to establish the association of single conditions with maturity. Furthermore, we have not used the configurations obtained using QCA for theory or typology building, but rather used it mostly to corroborate PLS-SEM results, which could be critiqued by some QCA scholars. Finally, the theoretical discussions on the different configurations as well as deviant cases would be part of future work.

⁹⁵ There are many more additional insights. However, since the goal of this paper was just to demonstrate a use case for blending QCA, NCA and PLS, we do not discuss practical implications of these findings for organisations. This will be part of our future work.

Table 3: Descriptive Statistics, Factor Loadings, Reliability Measures.

	Indicators	Mean	Std. Dev	Kurtosis	Skewness	Factor loading	AVE	Comp. rel.	Chron. Alpha
Service Operations Maturity (SO): Outcome (Y)	Event Mgt	3.110	1.421	-0.872	0.224	0.703	0.612	0.887	0.841
	Inc Mgt	4.228	1.323	-0.371	-0.576	0.878			
	Req Full	3.740	1.376	-0.791	-0.133	0.754			
	Prob Mgt	3.291	1.369	-0.803	0.117	0.814			
	Acc Mgt	3.535	1.302	-0.830	-0.024	0.749			
Conservative IT Strategy (CON)	Cons 1	5.031	1.501	-0.229	-0.684	0.842	0.608	0.820	0.691
	Cons 2	4.456	1.542	-0.933	-0.181	0.604			
	Cons 3	4.961	1.560	-0.284	-0.621	0.866			
Innovative IT Strategy (INN)	Inno 1	3.795	2.041	-1.412	0.043	0.951	0.856	0.947	0.919
	Inno 2	3.464	1.811	-0.978	0.233	0.947			
	Inno 3	4.102	1.749	-0.938	-0.132	0.875			
	Rel.Cap 2	4.574	1.493	-0.622	-0.401	0.895			
	Rel.Cap 3	4.339	1.381	-0.780	-0.007	0.911			
	Rel.Cap 4	4.417	1.466	-0.496	-0.234	0.734			
	Rel.Cap 5	4.323	1.479	-0.623	-0.275	0.799			
IT Employee Capability (Itempcap)	Emp.Cap 1	5.213	1.251	0.933	-0.980	0.813	0.620	0.919	0.897
	Emp.Cap 2	4.819	1.256	-0.581	-0.237	0.825			
	Emp.Cap 3	4.551	1.367	-0.926	-0.033	0.808			
	Emp.Cap 4	4.512	1.452	-0.792	-0.126	0.732			
	Emp.Cap 5	4.693	1.359	-0.787	-0.252	0.846			

	Indicators	Mean	Std. Dev	Kurtosis	Skewness	Factor loading	AVE	Comp. rel.	Chron. Alpha
	Emp.Cap 6	4.646	1.456	-1.075	-0.239	0.734			
	Emp.Cap 7	4.346	1.460	-0.764	-0.219	0.746			
System Criticality (Sys.Crit)	Sys.Crit 1	5.898	1.419	2.350	-1.561	0.787	0.694	0.918	0.887
	Sys.Crit 2	5.740	1.448	1.028	-1.254	0.902			
	Sys.Crit 3	5.756	1.389	1.112	-1.264	0.896			
	Sys.Crit 4	5.433	1.494	0.254	-0.892	0.862			
	Sys.Crit 5	5.393	1.796	-0.227	-0.960	0.700			
Service Provider Size (SP.Size)¹	Log ₁₀ (SP.Size)	2.099	0.818	0.234	0.197	1.00	1.00	1.00	1.00
Service Orientation (Service)	ProdVs.Service	5.448	1.892	-0.398	-0.968	0.881	0.789	0.882	0.733
	PhysVs.Inform	4.637	2.252	-1.363	-0.414	0.895			

Table 6: QCA intermediate solutions (configurations) and robustness checks.

Contextual Factors	Final Result						Robustness Checks														
	QCA 1 -> N=2, Incl=0.8			QCA 2 -> N=3, Incl=0.8			QCA 3 -> N=3, Incl=0.75			QCA 4 -> N=2, Incl=0.75											
	Below Average	Above Average		Below Average	Above Average		Below Average	Above Average		Below Average	Above Average										
1a	1b	1c	2a	2b	2c	3a	4a	4b	5a	5b	6a	6b	6c	7a	7b	7c	7d	8a	8b	8c	
System Criticality	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
IT Employee Capability	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
IT Strategy	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Conservative	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Innovative Profile	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Service Provider Size	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗	⊗
Service Oriented	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Consistency	0.92	0.80	0.91	0.82	0.85	0.86	0.92	0.82	0.86	0.86	0.86	0.82	0.86	0.86	0.81	0.91	0.92	0.75	0.82	0.85	
Raw Coverage	0.19	0.08	0.07	0.22	0.11	0.17	0.19	0.22	0.17	0.19	0.18	0.17	0.22	0.12	0.24	0.16	0.07	0.17	0.22	0.11	
Unique Coverage	0.12	0.02	0.06	0.11	0.04	0.12	0.19	0.16	0.12	0.09	0.08	0.05	0.10	0.12	0.03	0.03	0.05	0.04	0.05	0.04	
Overall Solution Consistency	0.90			0.81			0.92			0.87			0.81			0.86			0.79		
Overall Solution Coverage	0.27			0.38			0.19			0.27			0.39			0.41			0.45		
# of Cases	11	5	4	15	6	13	11	15	13	11	11	12	15	13	14	11	4	11	12	15	6
% contradictions (od)	0%	0%	0%	13%	0%	23%	0%	13%	23%	0%	0%	8%	13%	23%	7%	9%	0%	0%	17%	7%	0%
% of borderline cases (bc)	9%	20%	0%	27%	17%	31%	9%	27%	31%	0%	0%	0%	27%	31%	0%	9%	0%	9%	8%	27%	17%
% total	1%			9%			1%			0%			10%			3%			9%		
$\% \text{ total} = \frac{[\text{mean}(\text{od}) + 0.25 * \text{mean}(\text{bc})]}{2}$																					

Note: We also checked the effects on the final using threshold frequency (N=1) and found the results to be very robust. In addition to this we also checked the effects by dropping some conditions. While minor changes were observed with regards to number of subsolutions (configurations), the overall interpretation of the results remained unchanged. Hence we consider the results very robust.

Table 7: Compiling the results – Template for combined PLS-SEM, QCA and NCA results.

Methods ->	PLS-SEM		NCA		QCA ^(d)		Configurational Findings ^(d)
	Conditions (X)	Coeff ^(a)	Effect	Necessary Conditions ^(b)	Above Average	Below Average	
System Criticality (SYS)	0.161*	Small	Both are necessary for very high maturity (>0.9) with medium effect.	Presence (Strong)	-	Moderate: SYS (AND) EMP associated with 22% of the above average cases with a consistency of 0.85.	
IT Employee Capability (EMP)	0.235***	Small		Presence (Moderate)	Absence (Strong)		
Conservative IT Strategy (CON)	0.311***	Moderate	Ambidextrous strategy necessary for very high maturity (>0.9) with small effect (0.076).	Presence (Moderate)	Absence (Moderate)	Small: Undefined (con=0.9, cov=0.07) and Ambidextrous strategy (con=0.8, cov=0.08) are associated only with below average maturity.	
Innovative Strategy (INN)	-0.174	Small		Absence (Strong)	-		
SP Size (SPS)	0.242***	Small	Not necessary	Presence (Small)	Absence (Strong)	Moderate: ~SER (AND) SPS (con=0.86, cov=0.17) is associated with above average maturity, while SER (AND) ~SPS (con=0.92, cov=0.19) is associated with below average maturity.	
Service Orientation (SER)	-0.170**	Small	Not necessary, but negation of the condition is necessary with a small effect (0.035) ^(c) .	-	Presence (Moderate)		

a) * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

b) Although NCA indicates presence of necessary conditions, set membership of some conditions associated with even full maturity is less than 0.5. Therefore, we conclude that an above average membership of service provider size is

actually not necessary (NN) for above average maturity. Similarly, the two IT strategy conditions, system criticality, and IT employee capability are all only necessary for very high maturity.

- c) Comparing the NCA effect size for service orientation and its negation, we can conclude that being a product company is necessary for very high maturity (>0.95).
- d) One of the major limitations of QCA is that the current measures of fit (i.e. consistency and coverage) are only used to assess the set-theoretic importance of complex combinatorial solutions leading to the outcome but not the unique contribution of each individual condition (Liu et al. 2017). Therefore we make an assessment of the relative importance of a condition (i.e. Strong, Moderate and Small) based on 3 factors; (i) the number of configurations it is part of, (ii) it being a core or peripheral condition and (iii) its coverage proportional to the overall coverage. For example, system criticality (SYS) is a core condition and present across all 3 configurations associated with above average maturity. Hence its relative importance is strong. However, we cannot make any assessment (-) about service orientation (SER) for above average maturity. This is because one configuration (2b) is associated with its presence and another (2c) with its absence, both with almost equal coverage. On the contrary, the presence of service orientation (SER) is considered "moderate" for below average maturity, although it is associated with only one configuration (1a). This is because 1a has a large coverage (0.19) as compared to total (0.27) and in the other two configurations (1b and 1c) its presence or absence does not matter.

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