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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.

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. Delloitte [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- S ther 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 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.

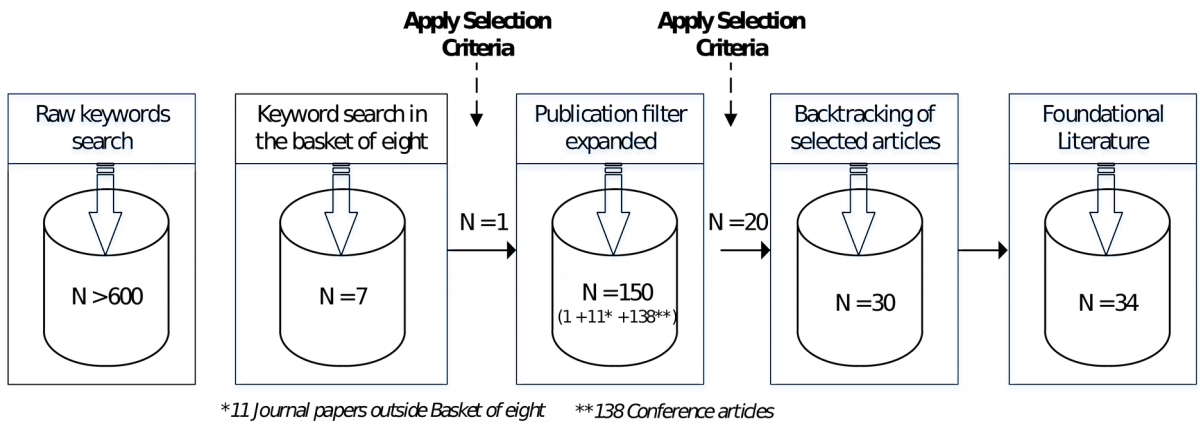

Figure 1. Literature review process and resulting number of article.

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], P ppelbu 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 Kr mer [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.

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].

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.

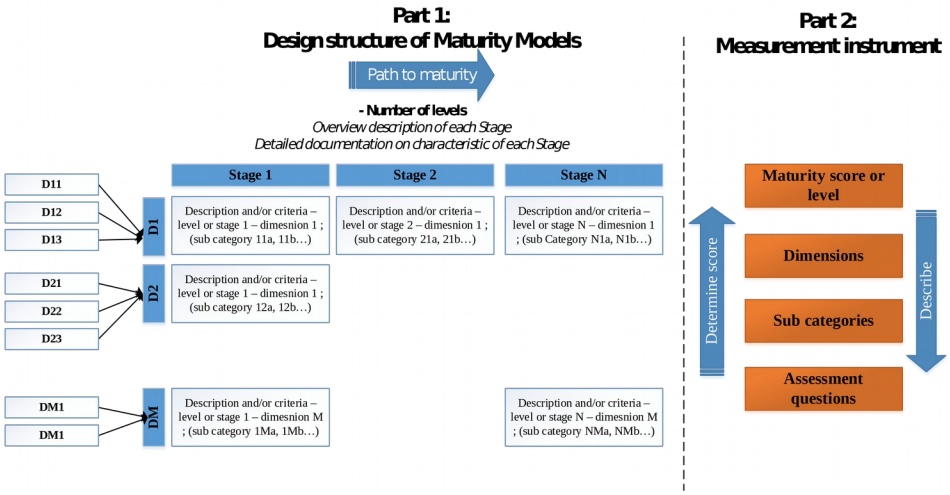

Figure 2. Schematic Representation of Generic Structure of the Maturity Model

2.3 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-S ther 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.

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]
1. Scope – Set the outer boundaries for model. **2. Design**- Determine architecture of the model. **3. Populate** - Identify dimensions and sub-categories, describing detailed description in form of statements. **4. Test** – Relevance, rigor, validity, reliability in terms of both construct and content. **5. Deploy** – Deploy in phases, first among collaborators, then target audience and finally to entire population. **6. Maintain** – If acceptance is achieved, design to handle volumes.	**1. Problem definition** – Determine scope, domain, target group. **2. Study existing Models** – Compare the problem with existing maturity model, review if there is need to develop new model. Document the study. **3. Design Strategy** – Determine design structure. Justify and document. **4. Iterative development process** – Select design level, approach, dimensions and tests the model iteratively. **5. Transfer concept & Evaluation** –Publications, software tool, etc. **6. Implementation of transfer media**- Target media in phases depending on the users. Release of voluminous documentation first or self-assessment questionnaires. **7. Evaluation of results** – This determines validation of the maturity model in reality. **8. Iterative Continuation** – Outcome of evaluation decides rejection, otherwise improve continuously.	**1. Suggested Stage model** – is based on developer's perspective; based on literature review and ideas from practitioners. **2. Conceptual model** – Maturity levels and detailed description are developed. Empirical methods i.e. case studies are adopted. **3. Theoretical model** – Theories explain levels, descriptions, relevance and path of evolution. Dimensions are derived theoretically and validated via focus groups. **4. Empirical model** - Each dimension is assigned numerical value and interrelated to a particular maturity level. A survey instrument for testing the model. **5. Revised stage model** – Compare the empirical model results with reality and revise model accordingly.

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-S ther 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.

2.4 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.

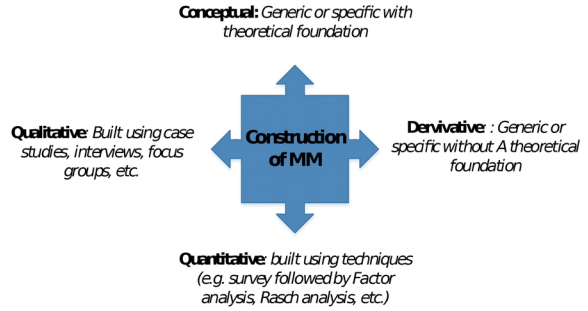

Figure 3. Methods adopted in building maturity model constructs.

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 /or derivative and empirical validation could definitely increase the rigor of maturity models.

2.5 Three Common Criticisms of Maturity Models

Maturity models have be swamped with criticisms with Nolan's evolutionary model facing the bulk of it with King and Kr mer [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 Kr mer [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-S ther 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.

3 Discussion & Conclusion: Towards Theoretically Grounded Maturity Models

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.

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 Kr mer [22], P ppelbu 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.

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.

Appendix 1

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

Concept			Characteristics	References
Basic	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		*General or domain specific*. 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 *people, process, technology or no clear distinction***.**	[26]
	Stakeholders		Development by *Academia, Practitioners, Government or combination*.	[11]
	Unit of Analysis		Usually at a level of *technology, process or organisations*	[11]
	Respondents		Provide empirical evidence. E.g. Partners and owners, Higher management (CEO, CIO, etc.), depending on the focus of the model.	[11] [26]
	Target Audience		Are the ones who would use the Maturity model e.g. Auditors, partners, higher management, managers, classified as *Management oriented or technology oriented.*	[11], [26]
	Documentation		Book, Journal, Webpage, etc. Detailed documentation reveals the rigor.	[38]
Design Factors	Representation	Composition	The basic structure for the model. *CMM-like, Likert- like questionnaires, Maturity Matrix or grids*. *Nolanisque-like or stage of growth model*. *Focus area model*.	[26] [9] [40]
		Reliability	Is the model verified and validated? Verification represents testing phase; test the model on a sample for accuracy. Validation is the degree to which the model represents reality. This is normally done after the model is published.	[26] [3]
		Mutability	Can the model be refaced from time to time to fit the context?	[26], [23]
		Path of maturation	Most of reviewed models in “IS” follow a linear, unidirectional path from lower maturity to higher maturity.	[30],[10]
		Dominant problems	Dominant problems are predictable primary concerns that the entity under maturation would face for each theorized stage.	[39] e.g. [18],[9]

	Constructs	Representation of Maturity	1. *Level of abstraction* – Corporate, Management or staff. Higher the level of abstraction lowers the number of dimensions. 2. *Number of Stages or levels*– 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. 3. *Stage fixed or Continuous* –Continuous models allow a scoring of characteristics at different levels; staged models require that all elements of one distinct level are achieved. 4. *Numeric Value* –Maturity score depicted using numbers. Purpose of use is comparative i.e. benchmarking. The most common way of visualising is *Spider cobweb* design. *Type 1* - Focus area maturity models (less popular) *Type 2* - 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). 5. *Purpose of use* – Descriptive, prescriptive, comparative or combination.	[11] E.g. [8], [30], [29], [31]. [34], [31], [6] [41], [40] [37], [26] [38]
		Maturity levels	Levels are archetypal states of maturity of the object that is assessed. Each level should have a set of distinct characteristics that are empirically testable.	[30], [34]
		Dimensions	Also termed as *Benchmark variables, process areas, Capability, and critical success factors*. *Cognitive capacity of users* – "Humans have limited cognitive capacities for memory, attention and perception". Hence limit first level dimensions from 5 to 7.	[26] [21]
		Sub-categories	These are second level variables on which the dimensions depend on. (Refer figure 2). E.g. BPMM with 30 sub categories. DyAMM with 16 dimensions.	 [12] [41]
	Assessment	Instantiation	*Self-assessment via Surveys* is most widely adopted instruments. Instantiation is mostly through web based software tool or an excel file. *Third party assessment or certification***s** 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], BPMM too is a process centric model [12], [10] is a technology centric; E-Government maturity model is a people centric maturity model [1].

Appendix 2

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

Approach / Model	Instrument				Instrument				Comments
	Conceptual	Qualitative	Quantitative	Derivative	Survey**	Third Party*	Certification	None	
Intranet Model [9]	●	●						●	Empirically derived usi

								ng *interviews* and prior literature ons	

								tage models used to propose a model.	
Analytics Maturity	●							●	

[10]								D e v e l o p e d t h r o u g h *a n e c d o t a l e v i d e n c e a n*	

								d prior experience. Surveys and intervi	

								ews to collection information. Used by num	

								b e r o f c o n s u l t a n c y s u r v e y s o n a n a l y t i c s

								.	
Business-IT alignment [25]	●			●	●	●			Constructs derived from *literature*, questionnaire derived from *anecdotal evidence & experience.*
Social media Business [18]	●			●				● Derived using academic *literature a*	

								nd consultancy maturity models taking i	

								n t o a c c o u n t s t e p s p r o p o s e d b y [3 9] .	
DyAMM [41]	●			●	●				Focus area maturity design. Proposed a new way of representing overall maturity in relationship with capability areas.
BI maturity model [23]	●		●	●		●		B	

								Idimensions derived from existing lit	

								erature, *Rasch algorithm* supported by c	

								luster analysis used to derive maturit

								y l e v e l s .	
BI maturity model [34]	●	●	●			●		B I m a t u r i t y a n d q u e s t i o n n a i r	

								e d e r i v e d f r o m *l* *i* *t* *e* *r* *a* *t* *u* *r* *e* , *R* *a* *s* *c* *h* *a* *l* *g* *o* *r* *i* *t*	

								hm supported by cluster analysis to de	

								r i v e m a t u r i t y l e v e l s .	
●●●BPMM dimensions (5) from literature and case studies. *Delphi Method* adopted iteratively and *longitudinal case study* to evaluate model. Business Intelligence Maturity [36]	●				●				Questionnaire of the existing BI MM [35]. *Euclidean distance* to calculate Maturity level of an organization; formula from SOA model [28]
Capability Maturity Model [31] ***● Business Process Maturity [12]	●			●			●	D e t a i l e d	

								and Comprehensive model built for practi	

								itioners.	
Process Management in Hospitals [5]	●	●	●		●				Theoretical approach to define dimensions, revised via focus groups and relevant questionnaire developed. *Rasch analysis* 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	

								l ; l e v e l s s h o w n a s *s i m p l e f i v e p e r c e n t i l*	

								es (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. *Simple addition & average* 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.*

Appendix 3

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

Approach / Model	Lifecycle	Evolutionary	Dialectal	Teleology	Comments
Intranet Model [9]	●		●	Each new stage represents a	

				s e t o f f e a t u r e s t h a t a r e s u p e r i o r t o t h e	

				old features, cumulative and unitary i	

				n nature; the article mentions an evol	

				utionary approach with survival of intr	

				a n e t , h o w e v e r d o e s n o t q u a l i f y u n d e r t h e	

				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).	
Analytics Maturity[10]	●	●	●	Si	

				ngle entity (use of analytics), however	

				there are glimpses of contingency vari	

				ables and one does not see a unitary p	

				ath atleastfrom stage 1 to stage 3.In	

				addition the objective is “competing	

				on analytics” which invokes survival	

				aspectofevolutionaryapproach.Adiale	

				ctical thesis (e.g. motivation of leader	

				s h i p t o s t a y i n s t a g e 2 o r 3) i s n o t i c e	

				d, similar to the intranet model.	
BITA [25]	●		●	Busine	

				s s I T a l i g n m e n t m o d e l b y L u f t m a n [2 5] i s	

				predominantly a lifecycle approach t	

				o m a t u r i t y . E v e n t p r o g r e s s i o n i s i r r e v e	

				rsible and linear. Dialectical approach	

				similar to the above two models are u	

				sed in form of enablers and inhibitors	

				Business IT alignment.	
●SMBP [18] 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	●		●		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.

certain individual dimensions are achieved.					
● DyAMM [41]					

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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