A Roadmap to the Collaboration Maturity Model (CollabMM) Evolution

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***Abstract* —** Organizations have been relying on collaboration for productivity improvement and knowledge sharing. The first step to foster collaboration in organizations is to explicit it. With this aim, the Collaboration Maturity Model (CollabMM) was proposed and evaluated. The lessons learned during model applications in previous work, pointed out the need to review both the model and its evaluation instruments. The literature review also showed some improvement opportunities. Therefore, the objective of this work is to develop a roadmap to highlight the main opportunities of evolution in CollabMM. These opportunities will compose our research agenda in this topic and guide future work.

Keywords - *collaboration, maturity model, CollabMM*

I. INTRODUCTION

In a competitive environment, organizations need flexibility to meet customers' demands, by offering customized and high-quality products and services. Collaboration has been required as an instrument to overcome these challenges [1][2]. Group work has turned out to be an important business strategy and organizations are interested in collaboration, aiming to improve productivity and knowledge sharing [3][4].

Despite recognizing that collaboration is advantageous, many organizations still do not know how to encourage it [5]. In this sense, Araujo and Borges [6] argue that one way to foster collaboration is to increase its visibility so that participants can reach a greater understanding and feel committed towards their work. This increased visibility can be obtained through explicit collaboration.

In order to enforce collaboration, Magdaleno et al. [7] proposed the Collaboration Maturity Model (CollabMM) and a corresponding method for implementing it. The aim was to support organizations in explicitly incorporating collaboration into their business processes, allowing it to be systematically enforced during process modeling.

The use of maturity models is an interesting way to assess organizations [8]. These models are usually divided in progressive maturity levels, allowing the organization to plan how to reach higher maturity levels and to evaluate their outcomes on achieving that. However, there are few guidelines on how to develop a maturity model [9] and they are usually defined in an ad-hoc manner. This was also the case of CollabMM, which was empirically built, inspired in maturity models from other domains and based on a literature review.

Since its creation, CollabMM was tested in different contexts. Initially, it was tested in two observational studies, in different organizations, to verify its applicability [10]. After that, it was also evaluated in a real setting in a big oil company in Brazil [11][12]. The lessons learned from these studies, pointed out the need to review the model, deepening its theoretical foundation and formalize the description of collaboration practices.

The objective of this work is to develop a roadmap to highlight the main opportunities of evolution in CollabMM. These opportunities will compose our research agenda in this topic and guide future work. Since the state of the art of collaboration maturity models indicates a scarcity of proposals [8], this roadmap can also contribute to direct future researches in this topic.

The remainder of this paper is structured as follows. Section 2 defines collaboration and its supporting aspects. Section 3 presents a review of maturity models properties, development approaches and applicability in different domains. In Section 4, the definition, instruments, and the lessons learned with CollabMM are summarized. Section 5 discusses the roadmap to future CollabMM evolution. Finally, Section 6 offers some concluding remarks.

II. COLLABORATION

The word collaboration derives from the latin *com* and *laborare* – meaning labor together. De Vreede and Briggs [3] define collaboration as making a joint effort toward a goal. Because of its objectivity and simplicity, we adopt the same definition. The main idea is that by collaborating, people combine their expertise, insights, and resources in order to perform a group activity, accomplishing more than they could as separate individuals [13][14].

The main advantages of collaboration can be summarized as follows [4][13]: reduction of time required to perform tasks; improvement of the ability to solve complex problems; increase of the ability to generate creative alternatives, discussion of the advantages and disadvantages of each alternative to select it viable and to make decisions; communication improvement; learning; personal satisfaction; and encouraging innovation.

Regardless of all these known benefits, achieving effective team collaboration remains a challenge

[3][14][15]. It is important to determine when collaboration is truly needed and in what intensity. The collaboration should only be adopted when it has the potential to produce better results than individuals working alone [15].

Collaboration may also face some challenges, such as: delays in carrying out tasks collaboratively; lack of work coordination; high cost of decision making; and resistance to knowledge sharing. In these cases, substantial time and resources are consumed in inefficient collaborative activities without yielding the desired benefits.

Despite these challenges, group work has gained space in organizations that have recognized its importance to business success [16]. However, collaboration processes need to be explicitly designed and managed to maximize the positive results of such an effort. To satisfy this goal, the first question that arises is: how to organize the various aspects of collaboration? The group supporting aspects, detailed in the next section, were our base to answer this question.

A. Group Supporting Aspects

The CSCW (*Computer Supported Cooperative Work*) research area boasts of extensive literature discussing the main aspects comprising group interaction and collaboration. The area usually adopts four group supporting aspects: communication, coordination, awareness and group memory [6][16-18]. These aspects traditionally support the specification of groupware tools. In this work, they were adopted to characterize collaboration activities, not especially concerning technology support.

Group supporting aspects cannot be considered alone, because they are closely interrelated and dependent on each other [6]. To collaborate, people have to exchange information (communication), organize the work (coordination) and operate together in a collective workspace (memory). Through awareness, the individual is informed about what is happening and get the necessary information about a certain task.

Group members must overcome distances through the establishment of **communication** channels among them. Participants need to communicate in order to coordinate their work, assign tasks, make decisions and solve problems. Within a group, the communication can be performed in real time (synchronous) or in different time (asynchronous). In synchronous mode, participants must be simultaneously available and the message sent is immediately received, improving the speed of communication. In asynchronous mode, time is flexible, messages can be received in a future and unknown moment, and participants have time to think before continuing the communication process.

Coordination organizes the group to guarantee that tasks are performed as expected, i.e., within an expected period of time, following a desired sequence and respecting existing constraints. Coordination should avoid conflicting tasks, while providing productivity to the group. Coordination comprises the pre-articulation of tasks, their follow-up and the post-articulation, or wrap-up, of group activities. Coordination may also deal with interpersonal conflicts such as competition and lack of orientation or responsibility. Coordination means 'to keep the group alive', stimulating contributions and establishing group dynamics.

Group memory records information related to the development of the group activity. The group memory preserves both the formal knowledge obtained through the interaction – documents, artifacts etc – and the informal knowledge – decisions, ideas, comments etc – the rationale through which artifacts had been created.

Finally, **awareness** relates to the understanding of others' activities in order to contextualize individual contributions [19]. Participants should clearly understand the group's common objective, the role of each member, what must be done, and the results and impacts of each member's activity.

III. Maturity Models

Maturity models have been designed to assess the maturity (i.e., competency, capability, level of sophistication) of a selected domain based on a comprehensive set of criteria [20]. The term was introduced and popularized by SEI (Software Engineering Institute) with the development of CMM (Capability Maturity Model) [21] - evolved into CMMI (Capability Maturity Model Integration) [22] - developed to assess the maturity or capability of software development processes in organizations. Nowadays, the concepts and structure of CMMI are clear, well understood and applied by industry [4].

A maturity model is a framework that describes, for a specific area of interest, a set of levels of sophistication at which activities in this area can be carried out [4]. Essentially, maturity models can be used: to evaluate and compare organizations' current situation, identifying opportunities for optimization; to establish goals and recommend actions for increasing the capability of a specific area within an organization; and as an instrument for controlling and measuring the success of an action [9].

A. Maturity Models Properties

Maturity models describe the development of a domain over time, and have the following properties [20][23]:

i) The development of a single domain is simplified and described with a limited number of maturity levels;
ii) Levels are characterized by certain requirements;
iii) Levels are cumulative, where higher levels are built on top of the requirements of lower ones;
iv) The number of levels may vary, but they are distinct, well-defined, and sequentially ordered, from an initial up to an ending level (the latter is the level of perfection);
v) There is a logical progression through levels and no levels can be skipped;
vi) Levels should be named with short labels that give a clear indication of the intent of the level;
vii) Levels definitions should be developed to expand their names and provide a summary of the major requirements and measures, especially those aspects that are new and not included in lower levels.

These common design principles coming from CMM, and appear to have wide practical acceptance. Therefore, in Section 5, we check CollabMM against these properties to verify if it satisfies all of them.

Although maturity models main characteristics are known, there are few guidelines on how to develop a maturity model [9]. Therefore, they are often constructed in an ad-hoc manner, as was the case of CollabMM. In order to review and formalize CollabMM, we investigated approaches that can bring theoretical foundation to this topic. This is the focus of the next section.

B. Maturity Models Development

Whilst maturity models are high in number and broad in application, there is little documentation on how to develop them [20]. Through a literature review, two kinds of approaches were identified: meta-models and methodologies.

Hain [16] proposes a meta-model for maturity models. It considers that a maturity model should be composed of both a *model,* which is a structured collection of elements that describe certain aspects of maturity in an organization; and an assessment or appraisal *method,* which specifies how to apply the model in order to assess an organizations' maturity. The meta-model helps to understand the two parts and its interrelations. This idea of model and method combination was already presented in CollabMM [10].

Another meta-model, proposed by Mettler et al. [24], simultaneously considers, the phases to the development and application of a maturity model. It is important to note that these development phases are somehow included in the following maturity models development methodology.

The framework, proposed by de Bruin et al. [20], presents a general methodology with generic phases that can be applied to the development of maturity models in different domains (Figure 1). Each phase provides inputs to the next ones and some of them may be performed iteratively. These phases are summarized below, since this methodology will be helpful in CollabMM review.

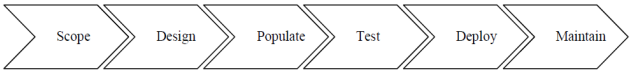

Figure 1. Maturity Model Development Phases [20]

The first phase in developing a maturity model is to determine the **scope** of the model. Model scope will set the outer boundaries for model application and use. The most significant decision made in this phase involves the focus of the model. Focus refers to which domain the maturity model would be targeted and applied. Focusing the domain will distinguish the proposed model from other existing ones. With the initial focus of the model identified, stakeholders from academia, industry, non-profits and government can be identified to assist in the development of the model.

The second phase of the proposed framework is to determine a **design** or architecture for the model that forms the basis for further development and application. The design of the model incorporates the needs of the intended audience and should define: *why* they seek to apply the model, *how* the model can be applied to varying organizational structures, *who* needs to be involved in applying the model, and *what* can be achieved through the model application.

The model design also needs to strike an appropriate balance between an often complex reality and model simplicity. A model that is oversimplified may not adequately reflect the complexities of the domain and may not provide sufficient meaningful information for the audience. Whilst a model that appears too complicated may limit interest, create confusion or raise the potential for incorrect application, resulting in misleading outcomes.

Once the scope and design of the model are agreed, the content of the model must be decided and **populated**. In this phase it is necessary to identify what needs to be measured in the maturity assessment and how this can be measured. The important issue is to select the combination of research methods that is most appropriate to the context of earlier scoping decisions and desired model outcomes. For instance, in a mature domain, the identification of domain components can be achieved through an extensive literature review. However, in a relatively new domain, it may not be possible to gather sufficient evidence through existing literature and other means of identification, such as experts' interviews or survey, are necessary.

Once a model is populated, it must be **tested** for relevance and rigor. It is important to test both the construct of the model and the model instruments for validity, reliability and generality. Construct validity is represented by both face and content validity. Face validity is assessed by whether good translations of the constructs have been achieved. The maturity model should be considered complete and accurate with respect to model scope. Content validity is assessed as to how completely the domain has been represented. The extent of the literature review and breadth of the domain provide a measure of content validity.

Once the maturity model has been judged to be complete, a reliability pilot test can be initiated. In addition to testing the model construct, it is necessary to test any assessment instruments for validity to ensure they measure what it was intended to and its reliability to ensure that the obtained results are accurate and repeatable. Usually, the assessment instrument can be a survey.

Following population and testing, the model must be made available for use and validation. **Deployment** includes initial organizational application and can consider the design collaborators as primary respondents. Moving to the second step in deployment, it is necessary to apply the model within entities that are independent of the model development.

Success in the deployment of the model requires that provisions be made to handle a high volume of model applications. This demands some form of repository in order to track model evolution. Evolution of the model will occur as the domain knowledge and model understanding broadens and deepens. If globalization of the model is achieved and certification of the model appliers is required, issues such as training material, certification processes, and so on will need to be considered. The continued relevance of a model will be ensured only by **maintaining** the model over time.

C. Maturity Models Applicability

Maturity models have proliferated across a multitude of domains since the concept of measuring maturity was introduced with CMM [20]. CMM was intended to guide efforts of software processes improvements. CMM has been proposed as an attempt to organize the body of knowledge in software engineering. It provides a framework for evaluating organizations and their software development processes regarding the set of practices suggested in the model [21].

The idea of evaluating process and organization capability has also evolved to BPM (Business Process Management). Business process management maturity models (BPMMM) have been proposed to help organizations determine their BPM implementation stage, by identifying strengths and weaknesses [25]. This evaluation can help them to envision an improvement plan comprising the activities needed to achieve a desired maturity model. Among these models, two of them are multidimensional and consider the human factor as one of their dimensions [25][26]. However, they do not investigate the level of existing collaboration among process participants.

A study conducted by Hain and Back [8] about the state of the art of collaboration maturity models, identified 55 models combining the areas of collaboration, knowledge management and e-learning. Among these models, there are academic and practical proposals and many of them were actually derived from CMM. However, the study also points out to a scarcity of models specifically dedicated to collaboration.

In particular, it is possible to mention the Enterprise Collaboration Maturity Model (ECMM) [4]. ECMM aims to assess the readiness of organizations for collaboration and interoperability, and help them establish a roadmap to improve these practices. ECMM took into consideration both the general requirements common to any maturity model (e.g., the model structure, and method of evaluation), and the technical requirements of collaboration and interoperability areas. Since this model was designed to a context of networked organizations or virtual ecosystems, it has many aspects of interoperability and does not specifically focus on collaboration among members within an organization.

Considering the lack of established collaboration maturity models, we also investigated KMMM (Knowledge Management Maturity Models), because collaboration and knowledge management areas have some overlapping [9]. There are many KMMMs [8][27] and they were compared and integrated in G-KMMM (General KMMM) [23]. The models specify different practices, but people, organization, process and technology are the main practices found in almost all of them. As a result of this analysis, G-KMMM adopts a structure with five maturity levels and has three main components: maturity levels, the set of characteristics of each level and practices.

The study of these related works, has contributed with insights to CollabMM roadmap, as discussed in Section 5.

IV. COLLABMM

As an attempt to organize a set of practices that can enhance collaboration in business processes, the Collaboration Maturity Model (CollabMM) was previously proposed [7]. CollabMM describes an evolutionary path in which organizations can achieve progressively higher maturity on collaboration,.

CollabMM was inspired in the maturity models cited in Section 3 (CMMI, KMMM and BPMM), although not intending to be compliant to any one of them. The following section describes the current definition of CollabMM maturity levels.

A. Collaboration Maturity Levels

CollabMM was organized into four maturity levels: **Ad-hoc**, **Planned**, **Aware** and **Reflexive**, as shown in Figure 2. Levels are a way of prioritizing practices for improving collaboration in a process. A specific level comprises a group of related practices that can be executed together, aiming at improving process collaborative capability.

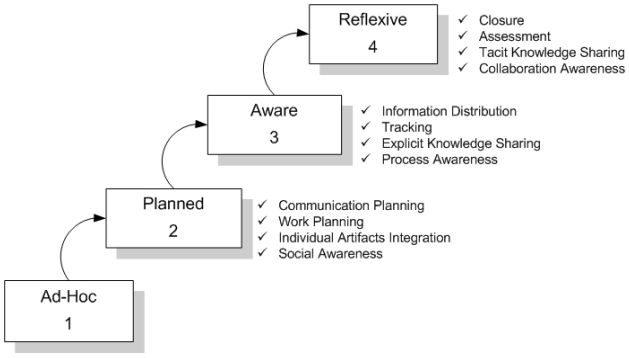

Figure 2. CollabMM Overview

The CollabMM collaborative levels can be summarized as follows. For ease of understanding, each level is depicted using a metaphor (Figure 3).

Level 1 – Ad-Hoc: In this level, collaboration is not explicitly represented in business processes. However, processes cannot be featured as with total absence of collaboration. Collaboration may happen, but it is still dependent on individual initiative and skills, and its success depends on the relationship and/or affinity among people.

Thus, collaboration is the result of individual effort (Figure 3) where people do not really act like a group. In these situations, a group of people spends great effort toward a common goal, because they may work independently of each other or without proper coordination. The aspects of communication, coordination, memory and awareness are present, but they are treated opportunistically.

Level 2 – Planned: In this level, business processes start to be modified aiming at including basic collaboration activities. Coordination is a strong aspect because groups need leadership and management in order to guide their work. The role of the coordinator is needed to centralize and

to manage activities, to foster commitment, and encouraging members to accomplish their goals. The leader is also responsible for assigning roles and responsibilities (Figure 3), for planning group work, and finally, for consolidating and integrating individual artifacts as the group result.

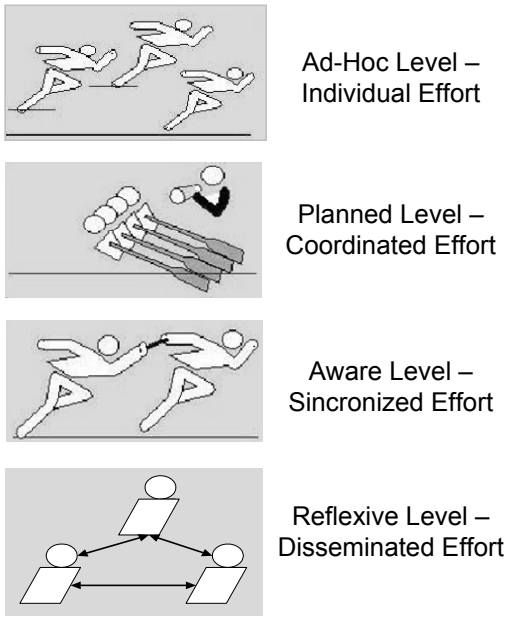

Figure 3. Metaphor for Collaboration Maturity Levels [14][28]

Level 3 – Aware: In this level, the process includes activities for monitoring and controlling how collaboration occurs. Group members are aware of their tasks and responsibilities and are committed towards them. Thus, it is no longer needed a centralized coordination of a leader. Group members work in a self-organized and simultaneously way to achieve the group goals.

Group members understand the process in which they are engaged, its main objectives, their roles and responsibilities and how their activities are related to others to perform these objectives (Figure 3). Additionally, processes at this level are characterized for decentralized coordination and shared knowledge, mainly through group artifacts.

Level 4 – Reflexive: In the reflexive level, processes are designed to provide self-understanding, identifying the relevance of the results which have been produced and sharing this knowledge inside the organization (Figure 3). Group members are aware of the manner in which the group collaborates during process execution, while process tacit knowledge is shared through ideas, opinions and experiences, thereby enhancing group memory.

Considering communication, processes must be formally concluded and their results communicated. Lessons learned can be captured; strengths and weaknesses are analyzed; success and challenges are shared; ideas for future improvements are collected; workgroup results are published and celebrated [1].

B. CollabMM instruments

CollabMM acts as a framework which organizes collaborative practices, without being committed to explain how to implement them. Therefore, beyond the maturity model, CollabMM is also composed by other instruments.

The first one is a detailed **method** that describes how to use the model for introducing collaborative practices into business processes. The method starts with the definition of which maturity level in CollabMM is expected to be reached by the process. Then, it establishes the steps that should be performed according to the selected collaboration maturity level. This method analyzes a business process model and defines a new model where collaborative practices are rendered explicit [10].

In addition, an instrument for **assessing** the collaboration maturity was defined based on a questionnaire and process observation. The questionnaire comprises a set of questions for systematically evaluating which collaboration practices were implemented in the organization. The questions were derived from each CollabMM level [11].

C. Lessons Learned with CollabMM

CollabMM has been used to assist two organizations in introducing different levels of collaboration in their business process models [10]. The results of these observational studies indicate model understandability and applicability. In addition, collaboration became explicit and participants could better recognize how collaboration was intended to occur along process enactment. These observations brought out evidence that CollabMM can be used to render more adequate business processes to collaboration support by helping organizations to move up collaboration levels.

CollabMM also has been discussed as a framework for assessing collaboration levels in a business process [11]. We worked in a real case from an oil and gas organization in Brazil, where a project has been implemented concerning issues such as: how to establish collaborative processes through the use of collaborative meeting rooms, and how to make information about business processes available and shared among participants during discussion sessions. In this context, CollabMM was applied in order to design the organizational processes for collaboration, discussing how the organization could enhance the use of collaborative technology, as well as to improve information sharing.

However, during these applications we also observed some improvements opportunities. First of all, the addition of collaboration activities may sometimes make the process more costly and time consuming. All processes within an organization bear space for improvement; however, a choice must be made of those which are relevant for having their collaboration appropriately supported. Therefore, we stressed the importance of selecting processes in which

collaboration can play a major role to improve results [11]. In this sense, it would be interesting to develop criteria for analyzing what processes would be most relevant to be encouraged with regard to collaboration.

The lessons learned from these studies, also pointed out the need to invest in model reviewing. Like in other maturity models, the main idea is to formalize its main components (collaboration maturity levels, levels characteristics, and practices). For instance, collaboration practices can be described according to CMMI structure, including purpose, goals, typical work products, and subpractices. The adoption of such kind of disseminated structure could enhance model comprehension and use.

Besides, we identified the need to establish metrics for calculating process indicators and formally define organization collaborative maturity levels. However, few instruments to measure collaboration exist and those are difficult to adapt outside the immediate context of a particular study [29]. In this sense, we started exploring the possibilities of using social networks [30] properties as an instrument to provide information about the collaboration existing among process participants [31][32].

Additionally, some steps of the method need more detailed guidelines to support process designers in their task of process tailoring for collaboration. For instance, the method can be enriched with document templates or supporting tools.

Finally, process patterns concerning the collaboration practices predicted in CollabMM could be defined in a way of being provided by process modeling tools and platforms.

V. COLLABMM ROADMAP

In this work we depict a roadmap to highlight the main opportunities of evolution in CollabMM. These opportunities will compose our research agenda in this topic and guide future work. Since the state of the art of collaboration maturity models indicates a scarcity of proposals [8], this roadmap can also contribute to direct future researches in this topic.

This roadmap is composed by the new ideas that arise from the literature review (Section 3) and the opportunities identified in CollabMM previous evaluation (Section 4). Starting with the former one, the first step is to check if CollabMM is compliant with maturity models properties. As justified in Table 1, we can conclude that CollabMM already satisfies almost every property. The last property is not satisfied and this need for levels formalization and metrics establishment was also identified in CollabMM lessons learned. Therefore, it will be the first item in our roadmap.

Table 1 – CollabMM Properties

Maturity Models Properties		CollabMM
i) The development of a single **domain** is simplified and described with a **limited number of maturity levels**	✔	The domain of interest is **collaboration** and CollabMM comprises **four** maturity levels.
ii) **Levels** are characterized by certain **requirements**	✔	Collaboration levels are characterized with requirements based on **group supporting aspects** (communication, coordination, memory and awareness) and they are also depicted using metaphors.
iii) **Levels are cumulative** where higher levels are built on top of the requirements of lower ones	✔	To achieve a level, CollabMM considers that the requirements of this level and from the lower ones have been satisfied.
iv) The number of **levels** may vary, but they are **distinct, well-defined, and sequentially ordered**, from an initial up to an ending level	✔	CollabMM has four distinct and ordered maturity levels, from level 1 to level 4.
v) There is a logical progression through levels and **no levels can be skipped**	✔	Since the shift to a collaborative environment is not trivial, it is realized in a gradual manner, because organizations will become more mature in the effective use of collaboration over time. Therefore, CollabMM also does not recommend that levels are skipped.
vi) **Levels** should be **named with short labels** that give a clear indication of the intent of the level	✔	Each collaboration maturity level has a label (Ad-hoc, Planned, Aware and Reflexive) that indicates the purpose of the level.
vii) **Levels definitions** should be developed to expand their names and provide a summary of the major requirements and measures	✘	Levels definitions are not in a clear state and the measurements of each level are not yet defined.

After that, CollabMM was analyzed to verify if it fulfills the maturity model development methodology requirements [20]. Table 2 details the results of this analysis where can be observed that three requirements could not be satisfied.

The first one is the need to think about the possibility of including other perspectives in the model (people/organization and technology). This decision should consider both the benefit of amplifying model capacity to

represent the collaboration domain and the challenges of using a multidimensional and complex model.

Second, as well as highlighted in lessons learned, CollabMM does not include the definition of collaboration metrics yet. One potential approach for that could be the use of social network properties and analysis [31]. Third, a repository to track model evolutions and to record the results of the model application could be established.

From the maturity models analyzed in Section 3, we also borrowed some ideas. First, most models have five maturity levels. Investigating this characteristic, we observed that, like CMM, they include an optimization level, which is not present in CollabMM, but can be an interesting improvement. We imagine that in this level, organizations can innovate in their collaboration practices and tools in order to maintain continuous focus on collaboration.

All the ideas presented to CollabMM future evolution can be classified in two groups: ideas regarding modifications in the model itself and ideas that refer to other instruments, such as method or supporting tools. They can be summarized in Figure 4.

Table 2 – CollabMM Development

Maturity Models Development Phases	Requirements		CollabMM
Scope	• Model Focus	✔	CollabMM is a domain specific model focused on collaboration.
	• Stakeholders	✔	CollabMM stakeholders are composed by a combination of academia, practitioners and government.
Design	• Needs of the target audience	✔	CollabMM is composed both of a model and a method that is able to guide this application.
	• Balance reality and complexity	✘	CollabMM adopted a simplified representation in stages that is largely used, but that only represents the perspective of processes. In the collaboration domain, the representation of people/organizations and technology can also be important issues. Thus, probably, to include this new information to broadly represent the reality, it will result in a multidimensional model (as BPMMM).
Populate	• Measurement	✘	CollabMM does not support this feature yet.
Test	• Model and instruments	✔	Both CollabMM and its instrument of assessment (questionnaire) were evaluated in different and real contexts.
Deploy	• Use and validation	✔	
Maintain	• Repository	✘	CollabMM does not have a repository to track model evolution.

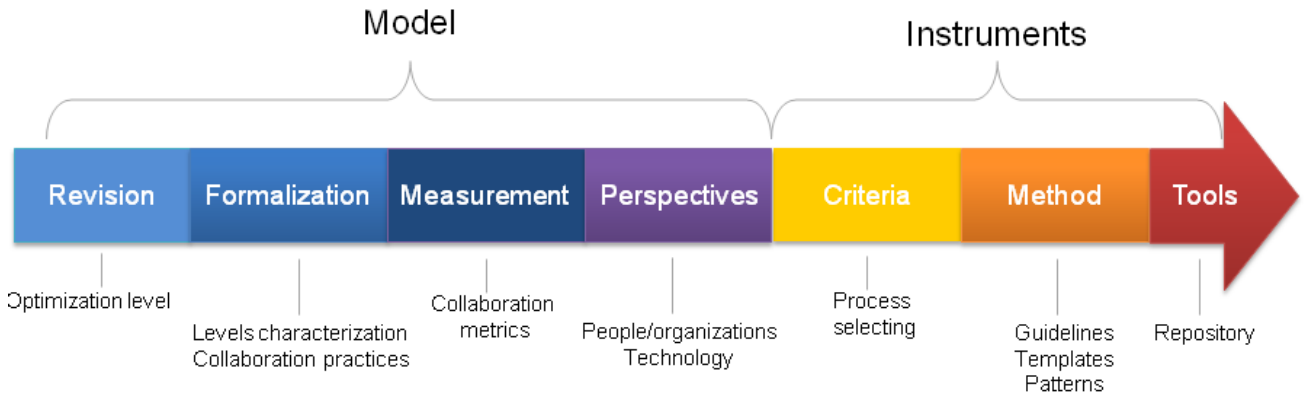

Figure 4. CollabMM RoadMap

VI. CONCLUSION

This work continues our research regarding collaboration maturity model. CollabMM was ad-hoc developed and, after some applications in different and real contexts, the observations indicated some improvement opportunities and a lack of theoretical foundation. Deeper analysis in the studies resulted in a set of lessons learned. Further investigations regarding literature review brought new maturity models, an established list of characteristics that they share, and new ideas to CollabMM review.

Therefore, this work consolidated the work done so far and presented a roadmap for future evolutions in CollabMM. The numerous research opportunities identified highlight the importance of these topics to helping organizations achieve sustained use of collaboration processes.

This roadmap will cover our research agenda in this topic and indicate future works. Since it highlights some open issues, it can also contribute to the scientific community building a common understanding of the challenges that must be faced, as well as identifying topic areas where research is lacking, such as collaboration measurement.

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