Chapter 7

A University-Industry Collaboration Practices Framework

'The point of equifinality is that it highlights the fact there are multiple routes to the same destination.' - [Ackoff et al., 2010]

In Chapter 5, a proposed framework for evaluating and improving UIC was outlined. Along with a UIC Systems Model (Chapter 6) and a UIC Maturity Model (Chapter 8), the proposed UIC Framework makes use of the UIC Practices Framework described in this chapter.

In developing the UIC Practices Framework, information gathered through a review of existing literature around barriers to, success factors and best practices for UIC, and the qualitative study described in Chapter 4 is utilised. The resulting framework can be used alone or in conjunction with Cynefin framework to understand UICs and improve their effectiveness.

7.1 Introduction

Factors are the aspects that influence UIC. In Chapter 4, we discussed barriers, that is, the factors that act as impediments or pose challenges to the success of UICs. In this chapter, I discuss success factors, the factors that positively influence UICs. The UIC Practices Framework is based on practices that help overcome the barriers or enable these success factors for effective UICs.

As described in Chapter 6 (Section 6.4.3), within the context of this thesis, 'practice' is defined as follows:

> A ***practice*** is a well-articulated specific action, or measure taken within an organization to *overcome* ***barriers*** and/or *enable* UIC ***success factors***.

In order to facilitate implementation of appropriate practices, a UIC practices framework is proposed based on the following considerations:

- The lack of a practical framework for establishing successful collaboration is acknowledged in the reviewed literature [Noble et al., 2017; Buys and Bursnall, 2007; Philbin, 2008].
- The literature around practices for successful collaboration is fragmented. This indicates a need for a comprehensive unified practices framework.
- In order for a practice to be adopted as a standard one it needs to be clearly articulated. Siegel's [Siegel et al., 2003b] comment in the context of TTO that 'there is a need to simply document the nature of these [organizational] practices' is equally valid for UIC, in general.
- In addition, there is a requirement for and interest in the recommendation of 'best practices' that can be used as a reference [Philbin, 2008] by UIC stakeholders. This again points to the need for documentation of UIC practices.

The research presented in this chapter aims to address the above considerations regarding availability of a comprehensive set of practices for practical application by proposing a UIC Practices Framework.

Based on practices identified through a review of existing literature and proposed during the qualitative research described in Chapter 4, a framework of practices is proposed, which can be used by stakeholders to improve the effectiveness of UICs. The underlying hypothesis for this framework is that the application of practices suitable to a particular context will improve the effectiveness of UIC.

7.2 Basis for the UIC Practices Framework

The UIC Systems Model described in Chapter 6 defines UIC practices, barriers and success factors. Specifically, it shows that practices are used to overcome barriers and to enable success factors. A relationship exists between these three elements and it was noted that practices adopted to enable a success factor may help overcome a barrier and vice versa. Barriers and success factors form the basis of the UIC Practices Framework as illustrated in this section.

7.2.1 Barriers to UIC

Barriers to UIC were categorized and discussed in Chapter 4. They were categorized as cultural barriers, legal barriers, administrative barriers, motivational barriers,

financial barriers, communication barriers, relevance barriers, and credibility barriers. Practices in the UIC Practices Framework aim to help stakeholders overcome these barriers.

7.2.2 Success Factors for UIC

The established benefits of UICs and associated potential barriers or challenges emphasise the need to explore the success factors behind effective UICs. I started the process of identifying the success factors with a review of this literature. This review uncovered a fragmented discussion around 'success factors'. This fragmentation can be inferred from Table 7.1, which shows that none of the existing literature covers all the success factors.

This fragmentation indicated that there is scope and a need to develop a comprehensive and coherent set of success factors that influence the initiation, formation, and effective management of UIC.

In order to improve the understanding and documentation of success factors, a new classification for success factors has been developed. I followed an iterative process of data analysis that included a combination of inductive and deductive approaches (Section 3.4) to develop the classification. The process began with Thune's classification [Thune, 2011] and resulted in adding, removing, and combining categories from other sources in the literature. For example, in the existing literature, communication is categorised under 'process factors' [Thune, 2011] or 'project management' [Barnes et al., 2002]. However, it appeared that communication is an important aspect as discussed in Section 7.4.6, and the emphasis required in terms of best practices for effective communication qualify it to be a separate category. Similarly, the significant influence of individuals involved in UICs, led to a separate categorisation of 'Personnel'.

The development of this classification was also influenced by the process of inspiration [Langley, 1999], or insight, intuition, and creativity of the researcher. Such influence is considered as an inevitable and uncodifiable feature (can not be transformed into explicit knowledge) [Weick, 1989].

Table 7.1 depicts the final classification of success factors and lists the factors in each category.

UIC is also affected by 'environmental' factors such as encouraging government policies and legislations, success history of collaboration, participation and interest of the community, and corporate stability [Kerka, 1997; Freeth, 2001; Barnes et al., 2002; John et al., 2015]. They provide an impetus to collaboration.

Studying the effect of environmental factors has not been considered within the

scope of this study as the main stakeholders identified for this research are university and industry, and they do not have much control over most of the environmental factors.

7.3 Categorization of UIC Practices

Because practices exist to overcome barriers and enable success factors, it is appropriate to categorize practices using the same categories as barriers or success factors. Once success factors were categorized as discussed above, it was noted that the categorization of success factors can adequately categorize the practices. Therefore, it was decided to categorize practices using the success factor categorization developed above in Section 7.2.2, depicted in Table 7.2, and summarized below.

- **Contextual.** This category covers practices, barriers and success factors that play a major role during the initiation and formation of a UIC.
- **Organizational.** This category covers practices, barriers, and success factors at organizational level that influence the success of a UIC. Organizational characteristics such as strategy and vision of a university, and absorptive capacity of an industry play an important role in establishing effective UICs.
- **Cultural adaptation.** This category covers practices, barriers and success factors related to differences in the cultural and organisational operation of universities and industry. These practices help universities and industry to adapt to the each other's cultures and requirements.
- **Operation and Management.** This category covers practices, barriers and success factors associated with effective operation and management of UICs.
- **Personnel.** This category covers practices, barriers and success factors associated with identifying suitable people for UIC. Motivated people play an important role in establishing collaboration and determining its outcome [John et al., 2015]. Individuals with an understanding of both academic and business worlds are considered the driving force behind successful partnerships [Edmondson et al., 2012; Plewa et al., 2013; Santoro and Betts, 2002]. 'Boundary spanners' have been identified as key players in establishing and sustaining relationships [Thune, 2007; Calder, 2007].
- **Communication.** Communication forms the very basis of a successful relationship [Thomas and Paul, 2018]. This category covers practices, barriers and success factors associated with communication. Communication encompasses

Table 7.1: Success Factors influencing University-Industry Collaboration

Category	Success factors	References
Contextual	Motivation	[Thune, 2007]
	Understanding of the diversity of UICs	[John et al., 2015; Edmondson et al., 2012; Perkmann and Salter, 2012; Bruneel et al., 2010; D'Este and Patel, 2007; Santoro and Bierly, 2006; Bloedon and Stokes, 1994]
	Partner selection	[Sjöö and Hellström, 2019; Rybnicek and Königsgruber, 2019; John et al., 2015; Perkmann and Salter, 2012; Thune, 2011; Plewa and Quester, 2007; Mora-Valentin et al., 2004; Barnes et al., 2002; Potworowski, 1989]
	Resource availability	[Sjöö and Hellström, 2019; Rybnicek and Königsgruber, 2019; Thune, 2011; D'Este and Patel, 2007; Galán-Muros and Plewa, 2016]
Organizational	**University:**	
	Strong academic leadership,	[John et al., 2015; Edmondson et al., 2012]
	Collaboration as a part of mission,	[John et al., 2015; D'Este and Patel, 2007]
	Conducive environment for engagement	[Sjöö and Hellström, 2019; John et al., 2015; Schofield, 2013; Edmondson et al., 2012; D'Este and Patel, 2007; Prigge, 2005]
	Technological relatedness	[Barbolla and Corredera, 2009; Philbin, 2008; Santoro and Bierly, 2006]
	Industry:	
	Strong commitment	[Thune, 2011]
	Absorptive capacity	[Barbolla and Corredera, 2009; Santoro and Bierly, 2006]
	Corporate stability	[Barnes et al., 2002]
Cultural adaptation	Adaptation	[Rybnicek and Königsgruber, 2019; Schofield, 2013; Perkmann and Salter, 2012; Prigge, 2005]
	Agreed timescale	[Edmondson et al., 2012; Perkmann and Salter, 2012]
	Balanced priorities	[Schofield, 2013; Barnes et al., 2002]
Operation and Management	Project selection	[Schofield, 2013; Perkmann and Salter, 2012; Philbin, 2008; Calder, 2007]
	Process management, Teamwork and Project manager	[Galán-Muros and Plewa, 2016; Schofield, 2013; Perkmann and Salter, 2012; Thune, 2011; Barnes et al., 2002; Barbolla and Corredera, 2009; Rohrbeck and Arnold, 2009; Potworowski, 1989]
	Win-win scenario ensuring equality	[Rybnicek and Königsgruber, 2019; Edmondson et al., 2012; Prigge, 2005]
	Formalization	[Perkmann and Salter, 2012; Thune, 2011]
	Shared vision and strategy	[Rybnicek and Königsgruber, 2019; Edmondson et al., 2012]
	Clear benefit	[Edmondson et al., 2012; Thune, 2011; Barnes et al., 2002; Barbolla and Corredera, 2009]
	Tangible outcome	[Thune, 2011; Barnes et al., 2002; Bloedon and Stokes, 1994; Potworowski, 1989]
	Wide impact	[Edmondson et al., 2012]
Personnel	Motivated and skilled	[Rybnicek and Königsgruber, 2019; John et al., 2015; Schofield, 2013; Barbolla and Corredera, 2009; D'Este and Patel, 2007]
	Boundary spanners / Agent	[Sjöö and Hellström, 2019; Edmondson et al., 2012; Philbin, 2008; Calder, 2007; Valentín, 2000; Bloedon and Stokes, 1994]
Communication	Information dissemination	[Rybnicek and Königsgruber, 2019; Schofield, 2013; Edmondson et al., 2012]
	Frequency, Diversity, Quality	[de Wit-de Vries et al., 2019; Rybnicek and Königsgruber, 2019; Edmondson et al., 2012; Rohrbeck and Arnold, 2009; Philbin, 2008; Thune, 2011; Mora-Valentin et al., 2004; Barnes et al., 2002]
Social capital	Positive attitude from partners	[Galán-Muros and Plewa, 2016; Bruneel et al., 2010; Thune, 2007; Mora-Valentin et al., 2004]
	Mutual respect and obligations	[Sjöö and Hellström, 2019; Bruneel et al., 2010; D'Este and Patel, 2007]
	Trust, Commitment	[Sjöö and Hellström, 2019; de Wit-de Vries et al., 2019; Galán-Muros and Plewa, 2016; Schofield, 2013; Edmondson et al., 2012; Bruneel et al., 2010; Philbin, 2008; Thune, 2011; Plewa and Quester, 2007; Santoro and Bierly, 2006; Mora-Valentin et al., 2004; Barnes et al., 2002]
	Common understanding	[Rybnicek and Königsgruber, 2019; Sjöö and Hellström, 2019; Schofield, 2013; Barbolla and Corredera, 2009; Calder, 2007; Potworowski, 1989]
	Access to resources with quality and amount of access	[D'Este and Patel, 2007; Santoro and Bierly, 2006]
	Continuity of personnel	[Thune, 2007; Barnes et al., 2002]
Legal	Transparent policy and processes	[Sjöö and Hellström, 2019; Dollinger et al., 2018; Schofield, 2013; Edmondson et al., 2012; Rohrbeck and Arnold, 2009; Santoro and Bierly, 2006; Potworowski, 1989; Prigge, 2005]
	Clear policy on publication	[Rohrbeck and Arnold, 2009; Valentín, 2000]
	Clearly defined IP rights	[Edmondson et al., 2012; Dollinger et al., 2018; Perkmann and Salter, 2012; Santoro and Bierly, 2006; Valentín, 2000; Potworowski, 1989]

several aspects such as codification (information dissemination), cooperatives, meetings, networks, and agreements [Kaymaz and Eryiğit, 2011]. Effective communication is a critical factor in the success of UIC as it can influence trust creation and maintenance, networking, and sharing of goals, which are important for fostering effective UICs [de Wit-de Vries et al., 2019; Thomas and Paul, 2018].

- **Social capital.** This category covers practices, barriers and success factors related to social capital. Social capital refers to the qualities and resources that encourage and support individual or collective action for the mutual benefit of people in a social network [Bourdieu; Portes, 1998]. The factors in this category play a crucial role in formation and success of UICs [Thune, 2007; Kerka, 1997].
- **Legal.** This category covers practices, barriers and success factors associated with legal aspects of UIC including the negotiation of intellectual property rights.

The next section presents the UIC Practices Framework developed to enable success factors and overcome barriers to effective UIC.

7.4 UIC Practices Framework

In this section, the UIC Practices Framework is described. The framework is organised as a coherently integrated and comprehensive set of practices to overcome the barriers and enable the success factors identified in Table 7.2. The framework is primarily based on the practices identified in the reviewed literature. However, it is further informed by the improvement approaches proposed during the qualitative study described in Chapter 4, which are mainly for action from universities.

Table 7.2 summarizes the UIC Practices Framework. It shows the practices involved along with the success factors enabled and barriers overcome by each of the practices. It also provides the source of each practice in the framework. LR denotes 'Literature review' and QS denotes the 'Qualitative Study' presented in Chapter 4 (Section 4.3).

Each of the practices are described in the following sub-sections.

Table 7.2: UIC Practices Framework

Practice Category	Recommended Practice	Source	Success Factors Enabled	Barriers Overcome
Contextual	Understand the diversity of UICs.	LR	Understanding of the diversity of UICs	
	Identify the motivation for Collaboration.	LR	Motivation, Technological relatedness	Unclear or unaligned relevance of research, perceived insufficient benefits
	Evaluate and select an appropriate partner.	LR	Partner selection, Resource availability, Absorptive capacity, Corporate stability	Difficulty in identifying stakeholders, limited industrial ability to utilize research results
Organizational	Adopt policies to encourage/facilitate UIC.	LR	Conducive environment, Resource availability	Administrative barriers
	Adopt strategies to encourage Collaboration.	LR	Collaboration as part of mission, Strong academic leadership	Administrative barriers
	Create a conducive environment for collaboration.	LR	Conducive environment	High cost, time, and effort; Difficulty in maintaining balance between regular duties and UIC, lack of established processes, inflexible bureaucracy
	Set up rewards and incentives.	LR	Conducive environment	Insufficient rewards and recognition for collaborative efforts
	Improve alumni relationships.	QS	Trust, Mutual respect and obligations	Lack of mutual appreciation, Unclear or unaligned relevance of academic research
Cultural adaptation	Understand each other's mission, processes, and adapt as appropriate.	LR, QS	Adaptation	Difference in motivation, goals, values, processes, Complexity of UIC
	Develop a shared vision of collaboration project.	LR	Balanced priorities	Difference in goals, Relevance barriers
	Create awareness of time requirements and agree upon time-scales.	LR, QS	Agreed time-scales	differing time-frames; perceived length of academic research; quicker business requirements
Operation and Management	Ensure a win-win situation.	LR	Win-win scenario ensuring equality	
	Establish realistic and mutually agreed aims	LR	Project selection, Shared vision and Strategy, Clear benefit	
	Manage collaborations.	LR	Process management, Teamwork and Project manager	Complexity of UIC
	Ensure fair and appropriate contributions from all stakeholders.	LR	Formalization	

	Aim at results aligned with industry goals.	LR	Clear benefit	Relevance barriers
	Plan for evaluation of collaboration.	LR	Tangible outcome, Wide impact	
Personnel	Identify and appoint suitable people.	LR	Motivated and skilled individuals	
	Appoint boundary spanners and/or agents.	LR	Boundary spanners / Agent	
	Ensure leadership involvement	LR	Strong leadership	
Communication	Establish effective communication.	LR	Frequency, Diversity and Quality of communication	Ineffective communication, lack of information about benefits, and opportunities
	Maintain accessible contact information	LR, QS	Quality of communication	Difficulty in contact
	Establish an effective dissemination strategy	LR, QS	Information dissemination	Lack of awareness of research
Social Capital	Adopt measures to increase trust and commitment.	LR	Trust, Commitment, Access to resources with quality and amount of access Continuity of personnel	Lack of safe collaboration mechanisms, Complexity of UIC
	Ensure mutual obligations, and common understanding.	LR	Positive attitude from partners, Mutual respect and obligations, Common understanding	Lack of mutual appreciation
Legal	Develop a common understanding of Intellectual Property (IP).	LR	Transparent policy and processes	Disagreements regarding IP rights
	Negotiate and clearly articulate IP rights.	LR	Clear policy on publication, Clearly defined IP rights	Disagreements regarding IP rights, ownership, publishing; contract negotiations; Information leakage

LR denotes 'Literature review' and **QS** denotes the 'Qualitative study' presented in Chapter 4 (Section 4.3)

7.4.1 Contextual Practices

7.4.1.1 Understand the diversity of UICs

Stakeholders should gain an understanding of the diversity of UICs.

In order to select a suitable mechanism, it is important to gain understanding of the variety of interactions possible between collaboration partners. Researchers emphasise the importance and need to understand the nature of partnerships, given a variety of collaborations are available to achieve different objectives [John et al., 2015; Farrell, 2010; D'Este and Patel, 2007; Bloedon and Stokes, 1994]. The diversity and nature of UICs have been discussed earlier in Chapter 2. Different types of UICs have different degrees of involvement and duration, and offer specific benefits such as application and commercialization, and enhanced capability to build competitive advantage. An understanding of the nature of those types will allow the stakeholders to make an informed decision about selecting an appropriate partnership.

A portfolio of the variety of UICs suitable to meet different requirements improves the effectiveness of collaboration [Bloedon and Stokes, 1994] by making required information about UICs available to the stakeholders [Tartari et al., 2012]. This can be attributed to the possibility of making an informed decision in selecting a type of UIC suitable to the particular context, for achieving the set objectives, and according to the characteristics of the knowledge under exchange within the context [Cassiman et al., 2010]. The characteristics of knowledge include explicit versus tacit, discipline, and the characteristics of individuals and organisations involved in the process [Bekkers and Freitas, 2008].

Several barriers to UIC exist as discussed in Chapter 4. An increased breadth of interaction is expected to overcome some of the cultural barriers to collaboration [Bruneel et al., 2010]. In addition, usage of a variety of UICs helps to ensure research efficiency, and gaining access to a variety of scientific and technical resources [Schartinger et al., 2002].

In addition to the literature reference for this practice, it is also supported by Ashby's Law of Requisite Variety [Ashby, 1961]. According to the Ashby's Law, the variety of challenges in a system need to be dealt with by an equal or greater variety of responses. UIC is, often, a complex system (as established in Chapter 6) with multiple factors influencing the system. In accordance with Ashby's Law, a combination of UIC types will help deal with these influencing factors leading to improved UIC [Landry et al., 2010].

7.4.1.2 Identify the motivation for Collaboration

Identification of motivations for collaboration is considered as a key collaboration capability [Chartered Accountants Australia and New Zealand and RMIT, 2017].

It is important to identify motivations and common areas before co-working or collaborating [Perkmann and Salter, 2012] as it will lead to increased commitment [Gorschek et al., 2006]. It will improve the effectiveness of collaboration.

UIC offers several benefits, which will motivate stakeholders to collaborate. Motivations vary from short-term problem solving to building long-term technological capability [Peças and Henriques, 2006; Potworowski, 1989]. Evidence of significance and strategic importance of collaborative research to the partner is also a motivating factor for collaboration [Barnes et al., 2002]. 'Business needs what the university has to offer because they won't succeed unless they innovate' [Chartered Accountants Australia and New Zealand, 2017].

Identification of motivations requires due time, discussion and deliberation. Such discussions can help overcome barriers such as unclear or misaligned relevance of research, and perceived insufficient benefits.

When identifying the motivation for collaboration, it is often important to consider other factors. For example, if the motivation is problem-solving, stakeholders should select a problem that possesses intellectual rigour and is motivating for both the partners. The problem should complement the academic expertise and be relevant to industry. Universities should also aim to select a generalizable problem within the partner organization as it will have a wider applicability leading to greater impact for the organization and the partnership. Such selection of a problem and solving it with a consideration of application is expected to enhance the impact of solving the problem.

Similarly, if the motivation is technology transfer, absorptive capacity of the partnering firm needs to be considered. Absorptive capacity can be defined as the capability of an organization to engage in a knowledge transfer activity with another institution in order to assimilate the information acquired during the process for creation of new knowledge and economic gain [Cohen and Levinthal, 1990]. It is considered as an additional attribute that contributes to successful technology transfer and sustained collaborative activities [Rahm et al., 2013; Philbin, 2008]. Technological relatedness (i.e. field of interest similar to academic research) and technological capability of industry increase its absorptive capacity [Santoro and Bierly, 2006]. For successful transfer of knowledge and technology, industrial partners should have the internal capability to absorb the research fully and transform it into marketable products [John et al., 2015].

On the other hand, if motivation for the university is to improve graduate skills through practical learning, the university may collaborate with industry for educational purposes. This collaboration can be in the form of internships or student group projects. Such experiences motivate each stakeholder. Students gain valuable employment-related skills and a better understanding of the role that they can play in society. Industry are exposed to new and emerging ideas, can influence curriculum, and are able to develop a pipeline of future employees. The university develops a better understanding of industry needs and challenges, and is able to respond through curriculum development and other collaborations including joint research projects.

The following recommendations are part of this practice:

- Universities should utilise a company's research portfolio to identify motivation and to determine opportunities for collaboration [Greitzer et al., 2010]. Industry is highly motivated to strike a partnership that will allow it to achieve something that it can't on its own. They reach out to universities to access the latest research.

- Research problem or motivation should be selected by conducting a joint workshop between industry partners and academics [Schubert and Fisher, 2009].

7.4.1.3 Evaluate and select an appropriate partner

The reviewed literature indicates the significance of selecting appropriate partners [Potworowski, 1989; Mora-Valentin et al., 2004]. Selection of an appropriate partner increases the effectiveness of collaboration. In order to select appropriate partners a method should be established to evaluate them. This will help in overcoming barriers such as difficulty in identifying stakeholders, and limited industrial ability to utilize research results.

When selecting a partner, it is important to recognize the variety of potential stakeholders. For example, Universities and Basic Research Institutes (e.g., Max-Planck Gesellschaft in Germany), Start-Up Companies, Applied Research Institutes (e.g., Fraunhofer Gesellschaft in Germany), Research based Companies (e.g., Siemens Corporate Technology), Development based Companies (e.g.,Siemens Business Units), and Consulting Companies are potential stakeholders [Rombach and Achatz, 2007].

In addition to recognizing the diversity of potential partners, it is also important to evaluate them against applicable indicators of success such as:

- Consider their goals, motivations and mutual benefits [Barnes et al., 2002;

Thune, 2011; Perkmann and Salter, 2012; American Association of State Colleges and Universities, 1987].

- Past experience and industrial familiarity [Potworowski, 1989] also influence collaboration success [Mora-Valentin et al., 2004]. Prior experience with stakeholders is important to consider because earlier short-term successful partnerships imply trusted relationships, which may lead to long-term strategic partnerships. At the same time, past failure may hinder future collaboration opportunities.

- Identification of complementary skills and objectives in matching collaborators is among the best practices for collaboration [Barnes et al., 2002; Strieter and Blalock, 2006; Sandberg et al., 2011; Potworowski, 1989]. 'The higher the complementarity of capabilities between partners, the higher the likelihood of mutual trust and the higher the level of mutual commitment' [Das and Teng, 2000; Chartered Accountants Australia and New Zealand, 2017].

- According to some studies geographic proximity plays a role and provides a clear advantage for initiating, establishing and maintaining collaborative relationships when stakeholders are located in the same region [Laursen et al., 2011; Tornatzky et al., 2002; Fritsch and Schwirten, 1999].

Finding industry partners is a very demanding and time-consuming process [Schubert and Fisher, 2009]. However, an appropriate partner selection will lead to increased commitment to UIC in their areas of interest [Sandberg et al., 2011].

7.4.2 Organizational Practices

7.4.2.1 Adopt policies to encourage/facilitate UIC

Policies must be adopted to encourage and support successful UICs.

The importance of policies in sustaining collaboration is recognized in the literature [Dollinger et al., 2018; Buys and Bursnall, 2007; Tornatzky et al., 2002; Stankiewicz, 1986]. Long-term development of industrially relevant academic R&D resources, communication, reduction of the financial/material costs of interaction, the resolution of organisational conflicts, and filling roles, which can facilitate collaborations at the university-industry interface have been identified as key policy areas for universities to overcome barriers to UIC [Stankiewicz, 1986].

Universities have begun to adopt measures such as creating and revising policies to meet the requirements of dynamic research environment and encourage UIC [Holbrook and Dahl, 2004]. For example, policies that aim to increase UIC at MIT have

been instrumental in establishing successful partnerships with industry. MIT has established a successful Industry Liaison Program to facilitate engagement between the university and corporates worldwide [John et al., 2015].

Literature also indicates that regional and national policies play a role in encouraging knowledge transfer from universities to industry, which signifies the need for policy initiatives at those levels [Siegel et al., 2007].

7.4.2.2 Adopt strategies to encourage Collaboration

Collaboration partners should adopt strategies to encourage collaboration [Siegel and Wright, 2015; John et al., 2015; Edmondson et al., 2012]. Successful collaborations are often the result of stakeholder commitment shown by making collaboration a part of their strategy and providing strong leadership [Edmondson et al., 2012; Rahm et al., 2013]. A good strategy for collaboration will include deliberate and informed planning in order to utilise existing collaborations and develop new collaborations. Such a strategy would address flexibility in working, investment in developing industrially relevant research and development resources, focus on creating long-term partnerships, and encouraging multi-disciplinary research.

The following recommendations are part of this practice:

- Include collaboration as part of the mission statement. Literature establishes the value of addressing 'collaboration' as part of an organisation's mission statement in creating successful collaboration. Collaboration influences the strategy of both universities and industry through mission [Philbin, 2008]. Universities that excel at collaboration often address collaboration as part of their mission statement. For example, the mission statement of the Imperial College London includes: 'We foster multidisciplinary working internally and collaborate widely externally' [John et al., 2015]; the goals of North Carolina State University include: '... fostering new partnerships, both internally and externally' [Tornatzky et al., 2002].

- A university's strategy should reflect the intent to engage with industry in terms of consideration of priorities, allocation of resources based on the type of UIC, and choice of area of emphasis as collaboration varies in type and extent among different disciplines [Siegel et al., 2007].

- Adopt a strategy with an objective to create long term partnerships and allow flexible working arrangements [Greitzer et al., 2010; Gorschek et al., 2006; Potworowski, 1989].

- Develop longer term collaborations. Longer term collaborations are expected to create more significant results for companies as industry can commercialize existing knowledge and innovative academic research results [Calder, 2007]. In order to create longer term collaborations in the future, industry can adopt a strategy to engage with university researchers even if the research is not directly supported through a contract [Greitzer et al., 2010] or not aligned with company's current area of operation [Sandberg et al., 2011].

- Cross-disciplinary research capacity is considered a key to successful collaboration [Edmondson et al., 2012]. The current business environment is pushing industries towards increased and faster innovation, which is often stimulated by and necessitates cross-disciplinary work. Universities should, therefore, develop and encourage multi-disciplinary programmes that deeply engage industry [Dollinger et al., 2018]. One way to foster cross-disciplinary engagement is to set-up an on-campus multidisciplinary institute in collaboration with industry to bring together experts from both worlds and across disciplines.

7.4.2.3 Create a conducive environment for collaboration

Organisations should create a conducive environment for collaboration which includes overall administrative support and supportive operational units [Dollinger et al., 2018; Edmondson et al., 2012; Prigge, 2005; Zinser, 1985]. For example, extensive university support and industrial participation in establishing research objectives and reviewing research progress and results should be ensured. Other aspects are internal organisational support for collaboration from initiation to utilisation of the UIC results, establishing new operational structures to encourage UIC, and promoting cross-disciplinary research. Such measures will encourage individuals and organisations to form UICs. These measures will also help in overcoming barriers such as high cost, time, and effort, difficulty in maintaining balance between regular duties and UIC, lack of established processes, and inflexible bureaucracy.

The following recommendations are part of this practice:

- internal support for technical and management oversight of UICs from contract through to exploitation of outputs [Greitzer et al., 2010].

- assigning accountability for the uptake of the output of collaboration by industry [Greitzer et al., 2010].

- establish support for UIC from senior officials [Prigge, 2005].

- adding appropriate resources for UICs, including Technology Transfer Offices [Siegel et al., 2003c].

- establish new structures to ensure successful collaboration [Edmondson et al., 2012; Prigge, 2005]. For example, the Center of Knowledge Interchange (CKI) established by Siemens at their partner university campuses [Edmondson et al., 2012] act as a single point of contact to manage strategic partnerships with universities. Another example is the restructuring of IP Management at UC Berkeley by establishing the new Intellectual Property and Industry Research Alliances office (IPIRA) [Burnside and Witkin, 2008]. The IPIRA provides services to academics to support their research, and facilitates collaboration.

7.4.2.4 Set up rewards and incentives

A system of incentives should be created in universities to recognize the efforts of academics participating in UIC. A similar approach could be adopted in industry.

Universities interested in improving UIC need to recognise and value the efforts of individuals involved in such collaborations [Veilleux and Queenton, 2015; Nielsen, 2017; Chartered Accountants Australia and New Zealand, 2017; Buys and Bursnall, 2007]. Rewards and incentives are expected to influence the motivation and level of engagement of individuals leading to more effective collaborations [Tseng et al., 2018; Potworowski, 1989]. They will help to overcome motivational barriers to UIC.

The following recommendations are part of this practice:

- Universities should design incentive systems that encourage researchers to engage with industry for utilization of research output to its full market potential [Walter et al., 2002].

- Associate funding, rewards, and promotions with the impact and relevance of collaborative projects [Nielsen, 2017; Strieter and Blalock, 2006; Starkey and Madan, 2001]. For example, the Industry Liaison Program at MIT adopts a revenue sharing scheme to offer incentives to university staff collaborating with industry [John et al., 2015].

- Establish formal awards and conduct acknowledgement events to recognize academics for industry engagement, inventions, and entrepreneurship [Tornatzky et al., 2002].

7.4.2.5 Improve alumni relationships

Universities should maintain a connection with their graduates working in industry. Through these connections universities can discuss industry problems and understand ways of working together to solve them. In addition, these alumni can become mentors for the present cohort of students, which will influence the future workforce.

Working with alumni figured as an important factor during the qualitative research presented in Chapter 4. Participants highlighted the value of alumni in building relationships with industry. Such relationship building can help overcome some of the cultural barriers such as a lack of mutual appreciation.

Alumni are considered among the greatest assets of a university [Chi et al., 2012]. On-going relationships with alumni can contribute to industry engagement in the form of guest lectures or internships [Matlay, 2011], and can provide funding for research and education [Straujuma and Gaile-Sarkane, 2018]. They can offer a practical perspective on research and education based on their experience [Matlay, 2011], which can help overcome relevance barriers such as unclear or misaligned relevance of academic research.

The importance of alumni is also emphasised by Prem Yapa of RMIT, who says that, 'By developing long-term relationships with the university, graduates help the university to re-learn' [Chartered Accountants Australia and New Zealand, 2017]. Successful entrepreneurs among alumni can guide the creation of curriculum and training [Phillips, 2018].

By leveraging their alumni network, universities can establish strong relationships with industry and increase their chances of developing more effective and successful collaborations [John et al., 2015].

7.4.3 Cultural adaptation Practices

7.4.3.1 Understand each other's mission, processes, and adapt as appropriate

Industry and university leaders need to develop an understanding of each other's mission and processes. Stakeholders need to listen to each other and seek ways to work together. While differences in the culture and philosophies of collaborating partners often bring more creativity to the table, strategic alliances between them need to be nurtured carefully over a period of time to arrive at desired stability in the relationship [Ehrismann and Patel, 2015].

In Chapter 4, cultural differences were identified as one of the main barriers and challenges to UIC. There is a need for universities and industry to adapt to the each

other's cultures and requirements [Burquel, 1997]. Partners should learn about each other, allow each other to express themselves, consider their perspectives, accept differences, and appeal to their highest motives. Developing mutual understanding of mission [Rohrbeck and Arnold, 2009] and processes will help to overcome the cultural barriers through adaptation [Prigge, 2005]. A practical way to achieve this could be to begin collaboration at a small scale, such as internships or research co-supervision so that partners gain experience and mutual understanding of their capabilities.

It is important for universities to listen to industry [Edmondson et al., 2012] and familiarise university researchers with the partner industry and management practices followed by them [Potworowski, 1989] in order to gain better understanding of the business world. This is important as industries are like customers of universities, who are usually investing resources in UICs.

The following recommendations are part of this practice:

- Create personal linkages as they will provide an opportunity for industry and universities to better understand each other [Prigge, 2005]. 'Ensure that everyone has a voice and is treated respectfully' [Strieter and Blalock, 2006]. A collaboration is likely to fail if the partners lack listening skills and understanding. For example, partnerships in which Nokia continued investing heavily in terms of money while university was not listening to the company, eventually failed with no meaningful results for the comapny [Edmondson et al., 2012].

- Industry should be 'proactive in their efforts to bridge the cultural gap with academia' [Siegel et al., 2003c]. This was also recommended during the qualitative study presented in Chapter 4.

- Learn conflict management in the process of UIC so that differences can be overcome [de Wit-de Vries et al., 2019].

- Adopt measures to increase awareness among researchers about products and their development life-cycle as emphasised in the qualitative study detailed in Chapter 4. The participants of the study expressed the view that understanding the real product of a business and its contributing environment will lead to increased effectiveness of UIC by reducing the cultural gap. It will also broaden the perspective of researchers about their own work.

7.4.3.2 Develop a shared vision of collaboration project

UIC stakeholders must work together to develop a shared vision.

Stakeholders should share their own vision [Greitzer et al., 2010] as a starting point for developing a common vision among collaborators [Strieter and Blalock, 2006; Rohrbeck and Arnold, 2009]. This requires identifying common ground [Siegel et al., 2003a]. Creating a shared vision will increase the sense of shared ownership of collaborative work and help overcome cultural and relevance barriers. Once a shared vision is established, stakeholders should proceed slowly with their UIC.

7.4.3.3 Create awareness of time requirements and agree upon timescales

UIC partners should consider the mutual time requirements and agree upon a time-line for UICs.

Differing time-frames are considered one of the main cultural barriers to collaboration (Sections 4.2 and 4.3.5). In order to overcome this barrier, it is important that stakeholders understand each other's timing requirements. For example, universities should understand timing requirements associated with the commercialisation of university research in a competitive market [Siegel et al., 2003c]. Such understanding can be developed by familiarising researchers with industrial practices [Potworowski, 1989] and adopting measures to increase awareness among researchers about products and their development life-cycle as emphasised in the qualitative study detailed in Chapter 4.

Stakeholders should jointly agree to time-scales and follow them strictly [Schubert and Fisher, 2009]. 'Agreeing upon time-scales' is among recommended practices for overcoming barriers related to time-frames (Sections 4.2 and 4.3.5), and has proven to be a success factor for UICs [Barnes et al., 2002].

Participants in the qualitative study described in Chapter 4 suggest that universities should identify areas where they can collaborate with industry to produce results in shorter time-frames than is typically the case. For example, projects that run over a semester are preferable to projects that run over several years. They note that successful short-term collaboration has a potential to lead to long-term mutual benefits.

7.4.4 Operation and Management Practices

7.4.4.1 Ensure a win-win situation

Stakeholders should identify a win-win situation and agree upon it. A win-win situation is where each stakeholder gains benefits out of UIC.

The perspective of each partner should be considered regarding the value of collaboration to ensure that there is some benefit in it for each partner [Chartered

Accountants Australia and New Zealand, 2017]. Proper attention must be paid to ensure that the benefits of collaboration are commensurate with the time, effort and investment of the companies [Barnes et al., 2002; Chartered Accountants Australia and New Zealand, 2017].

For successful UIC, an appropriate balance is required between academic and industrial objectives and priorities [Barnes et al., 2002]. Ensured mutual benefits are expected to have greater impact on success and lead to better results [Barnes et al., 2002; Edmondson et al., 2012]. Thus, 'win-win' scenarios are considered imperative [Prigge, 2005].

7.4.4.2 Establish realistic and mutually agreed aims

Literature emphasises the value of realistic and mutually agreed aims. UIC partners should have discussions during the early phase of collaboration to clearly identify, define and agree upon the objectives of collaboration. It is important to 'define specific collaboration outputs that can provide value to the company' [Greitzer et al., 2010]. Clear definition of deliverables during UIC formation leads to more effective collaborations [Potworowski, 1989].

The following recommendations are part of this practice:

- Make realistic aims for a UIC [Chartered Accountants Australia and New Zealand, 2017].
- Ensure mutual agreement on the goals and objectives when commencing a UIC [Chartered Accountants Australia and New Zealand, 2017].

7.4.4.3 Manage Collaborations

It is important to manage UICs to ensure success. The main aspects of management are related to objectives, roles and responsibilities, planning and execution, risk management, and progress monitoring. Adopting a framework to manage the collaboration process will help in monitoring, course-correction during the collaboration process, and achieving the set goals.

Good project management has been identified as a UIC success factor [Butcher and Jeffrey, 2007] in analysis of case study based projects [Barnes et al., 2002, 2006]. A successful collaboration requires informed planning [Zinser, 1985], proper preparation, aligned goals of collaboration partners [Dean et al., 2006], regular contact, and progress monitoring [Nielsen et al., 2013; Thune, 2011; Barbolla and Corredera, 2009; Peças and Henriques, 2006; Potworowski, 1989].

The following recommendations are part of this practice:

- 'Clearly define the problem' [Strieter and Blalock, 2006].
- 'Clearly define the objectives' [Barnes et al., 2006]. If there is no clarity regarding the objectives of a UIC, or the partners are not sure about the benefits for them, it will be difficult to drive the partnership successfully. Clarity in objectives can be achieved by spending time in understanding each other's requirements and defining the project's strategic context as part of the selection process for collaboration opportunities [Greitzer et al., 2010].
- Define UIC processes and a plan of work [Strieter and Blalock, 2006].
- Define roles and responsibilities to ensure timely progress and its monitoring.
- Minimize risk by recognizing and documenting risks/impediments up-front and agreeing upon a risk-mitigation strategy [Prigge, 2005; Gorschek et al., 2006].
- Clearly define project milestones and employ regular progress monitoring [Barnes et al., 2006].

7.4.4.4 Ensure fair and appropriate contributions from all stakeholders

UIC partners must consider everyone's perspective and ensure fair contributions. There should be clear articulation of the amount of active contribution expected from the partners at the beginning of the UIC.

The following recommendations are part of this practice:

- Ensure clear communication of the role of each partner in a collaboration [Barnes et al., 2002].
- Agree upon and clearly communicate the responsibilities of each UIC partner from the very beginning [Barnes et al., 2002].
- Identify and agree upon key performance indicators for a UIC. Ensure clear division of labour and management in accordance with them [Rohrbeck and Arnold, 2009].
- Reach agreement that contributions are fair and appropriate.

7.4.4.5 Aim for results aligned with industry goals

It is important to aim for results aligned with industry goals. A strong interest in utilising the outcomes of UIC is a significant factor in the success of UIC [Barbolla and Corredera, 2009; Schofield, 2013]. The characteristics identified regarding

research results that lead to successful collaboration are industry need-orientation, industry goal alignment, deployment impact, industry benefits, and innovativeness [Sandberg et al., 2011].

Often, there is a lack of communication regarding the relevance of university research to industry. It is recommended that universities should adopt a strategy to demonstrate the impact and benefits of their research results to industry. This will help overcome relevance barriers, and lead to increased adoption and commercialization of research output by industry. One way to demonstrate the impact and benefits of research is outlined in [Awasthy et al., 2016] (reproduced in Appendix A).

7.4.4.6 Plan for evaluation of collaboration

It is important to plan for evaluation of UIC. Stakeholders need to agree upon performance indicators and utilize these indicators to measure the success of UIC.

The following recommendations are part of this practice:

- 'Create measures to assess the impact of academic research on practice' [Starkey and Madan, 2001].

- Evaluate UIC to provide evidence of outcomes and impact [Strieter and Blalock, 2006; Chartered Accountants Australia and New Zealand, 2017]. Impact of research on industry practice should be assessed [Starkey and Madan, 2001] as evidence of the outcome associated with greater impact leads to successful collaborations [Schubert and Fisher, 2009]. This can be attributed to greater commitment from the partners owing to the significance of results.

- Use the results of evaluation to determine if the collaboration requires modification, improvement, expansion to maximize success or should be terminated [Strieter and Blalock, 2006].

7.4.5 Personnel Practices

7.4.5.1 Identify and appoint suitable people

Appointing the right and capable people is important for the success of a UIC. The characteristics of individuals influence the effectiveness of collaboration. Universities and industry should identify and appoint staff and faculty who are suitable for UIC.

Motivated individuals play an important role in establishing collaborations and determining their outcomes. Individuals with an understanding of both academic

and business worlds are often the driving force behind successful partnerships [Edmondson et al., 2012; Plewa et al., 2013; Santoro and Betts, 2002]. In addition, '...achieving a high level of collaboration depends on participants who contribute an openness to change, a willingness to cooperate, and a high level of trust' [Jassawalla and Sashittal, 1998].

As recognized earlier, universities and industry are often complex systems. Hence, individuals who understand the dynamics of both systems are expected to play an effective role in UICs. The benefits of hiring such people have been demonstrated by top universities in terms of industry engagements [The Australian National University, 2017; Tornatzky et al., 2002]. They hired nationally prominent scientists with backgrounds in industry and/or entrepreneurship.

The following recommendations are part of this practice:

- 'Select researchers who will understand company practices and technology goals' [Greitzer et al., 2010].
- Develop a pool of academics with business experience and deep understanding of industry [Edmondson et al., 2012].
- Hire individuals with experience in industry [Siegel et al., 2003c].
- Industry should 'hire technology managers with university experience' [Siegel et al., 2003c].

7.4.5.2 Appoint boundary spanners and/or agents

UIC partners should identify and appoint individuals as boundary spanners and/or agents dedicated to improving the effectiveness of UIC.

The term 'boundary spanners' is widely used to refer to an individual who can cross the formal boundaries of a department or organisation and/or has a cross-disciplinary or inter-organizational social network in which they operate [Chartered Accountants Australia and New Zealand, 2017]. They have a key capability to stimulate communication within their network and mobilize or reconfigure various required resources. 'Boundary spanners' have been identified as key players in establishing and sustaining effective UICs [Thune, 2007; Calder, 2007].

Boundary spanners influence the success of a collaboration in various ways:

- they act as a conduit for dissemination of tacit knowledge [Chartered Accountants Australia and New Zealand, 2017],
- they enable wider dissemination of research results to teams engaged in development and manufacturing within stakeholder companies, and

- they provide feedback from industry practitioners to academic researchers to help in maintaining research relevance and alignment with the industry requirement [Greitzer et al., 2010].

Several researchers extol the worth of an 'agent' or a champion [Bstieler et al., 2015] in ensuring actual knowledge transfer during UIC [Bloedon and Stokes, 1994; Calder, 2007; Prigge, 2005]. These agents also perform monitoring, management and administration of UIC. Further endorsing the idea of an agent is the Process Model [Philbin, 2008] in which collaboration agents are an important element. According to the model, an agent is responsible for personally driving the collaboration forward and achieving its set objectives.

The following recommendations are part of this practice:

- 'Hire managers/research administrators with a strategic vision, who can serve as effective boundary-spanners' [Siegel et al., 2003c]".

- 'Select boundary-spanning project managers with three key attributes: In-depth knowledge of the technology needs in the area of interest; the inclination to network across functional and organizational boundaries, and the ability to make connections between research and opportunities for product applications' [Greitzer et al., 2010].

- Industry should identify and appoint individuals, who can play the role of an agent or champion in UIC.

7.4.5.3 Ensure leadership involvement

UIC partners should ensure leadership involvement. The success of a collaboration is influenced by leadership involvement through encouraging engagement, creating a conducive environment, and demonstrating commitment.

Collaborative initiatives driven by top leadership are expected to motivate the engagement of researchers and practitioners. A study confirms that the priority given by senior management to new product development through collaboration with external partners affects the level of collaboration [Jassawalla and Sashittal, 1998].

Leaders have decision making power to ensure that right people are allocated to drive collaborations, budget decisions are appropriate and timely, and required resources are available. This is expected to increase the chances of UIC success.

Entrepreneurial behaviour of a leader has the potential to directly impact the effectiveness of an organisation by inspiring other individuals to engage [Walter et al., 2002; John et al., 2015]. For example, the senior leadership at MIT that encouraged

collaboration with industry laid critical foundations for successful UICs, and entrepreneurship [John et al., 2015].

7.4.6 Communication Practices

7.4.6.1 Establish effective communication

Communication among participants is critical in order to coordinate work and manage UIC effectively. Stakeholders should adopt measures to improve communication between them, such as regular contact to meet and talk, encouraging bi-directional flow of information, and using virtual meeting tools. This will help overcome barriers such as a lack of information about benefits and opportunities. If UIC partners are geographically separated, utilising various modes of communications such as mobile, and digital media will be effective. Digital modes are also useful and effective during challenging situations requiring individuals to communicate in virtual environment.

Improvement in frequency and quality of communication between university and industry [de Wit-de Vries et al., 2019; Butcher and Jeffrey, 2007; Plewa et al., 2013; Thune, 2011; Kerka, 1997; Santoro and Bierly, 2006], especially bi-directional communication [Schartinger et al., 2002; Kaymaz and Eryiğit, 2011] are the key ingredients for successful collaborations [Mora-Valentin et al., 2004]. In addition, communicating the progress of UIC and its benefits within an organisation will encourage individuals to engage in future collaborations [Buys and Bursnall, 2007].

The following recommendations are part of this practice:

- Establish strong communication linkages between stakeholders [Greitzer et al., 2010].
- Conduct face-to-face meetings on a regular basis as required and when possible [Greitzer et al., 2010].
- 'Develop an overall communication routine to supplement the meetings' [Greitzer et al., 2010].
- Encourage exchange or mobilisation of individuals, both company to university and university to company [Greitzer et al., 2010].
- Encourage a two-way exchange of information between UIC partners [Edmondson et al., 2012].
- Organize co-located, shared and open office space and team-building activities to improve communication [Rohrbeck and Arnold, 2009].

- Organizations should build broad awareness of UICs within their organizations [Greitzer et al., 2010].
- Industry should provide feedback to the university team on alignment of UICs with their needs [Greitzer et al., 2010].

7.4.6.2 Maintain accessible contact information

Universities should maintain an accessible record of research results and associated contact persons. This will help overcome barriers such as difficulty in identifying relevant contacts.

A lack of visibility of university research projects and associated contacts was identified as a barrier to UIC during the qualitative study described in Chapter 4. Industry found it difficult to find the right collaborator to talk to with confidence and trust. In the reviewed literature, this lack of visibility of research is identified as a need to improve the search processes between companies and academics.[Chartered Accountants Australia and New Zealand, 2017]. An unstructured search process based on informal networks is considered ineffective in identifying relevant and appropriate contacts.

The following recommendations are part of this practice:

- Establish single points of contact and coordinating structures via which companies can explore potential research relationships [Tornatzky et al., 2002].
- Create databases of faculty interests, resources and competencies, and associated Web-based search engines that help companies find faculty members, equipment, facilities, and projects that match their needs [Tornatzky et al., 2002]. An example of this is ANU's TechBroker [Flint, Shayne, 2018] application.

7.4.6.3 Establish an effective dissemination strategy

Universities should establish an effective dissemination strategy.

Dissemination is a planned process of communicating research findings with consideration of the target audience. Effective dissemination enables the audience to quickly maximise benefits from research outputs [Wilson et al., 2010]. It will help overcome barriers such as a lack of awareness of research, and lack of information about benefits, and opportunities [Garousi et al., 2016].

Dissemination of research results should target participants, who can translate them into practice [Ripoll Feliu and Diaz Rodriguez, 2017; Fritz, 2016; Edwards,

2015]. This will provide benefits to the wider community [Knoepke et al., 2019]. It could also lead to obtaining new funding sources from organisations interested in the research results [Chen et al., 2010]. In some disciplines such as medical research, dissemination of research findings is emphasised as an ethical responsibility of a researcher [Pearn, 1995].

However, there are challenges to wide and timely dissemination [Chen et al., 2010]. The involvement of multiple and different types of stakeholders partly contributes to making the process of dissemination more complex [Alexander et al., 2018]. In addition, the narrow definition of dissemination among academics as publication in journals could delay the impact of discoveries [Group et al., 2013].

A lack of visibility of research results has been cited as a barrier to university-industry collaboration in the literature [Starkey and Madan, 2001] and during the qualitative study described in Chapter 4.

All these factors indicate that there is a need for academics to improve the dissemination of their research results with consideration to access and relevance of work, and style of academic writing [Starkey and Madan, 2001; Straub and Ang, 2008].

At a broader level, the qualitative study described in Chapter 4 identified a need to communicate the capabilities, results of research, and potential impact of these results in order to encourage industry interest in UIC.

The following recommendations are part of this practice:

- Highlight successful UICs on university websites. For example, the universities with a history of successful UICs had demonstrated their efforts to disseminate the value of research output by highlighting and extolling the successes of partnerships on university Web sites and through media, developing myths and stories about industrial engagement or entrepreneurial success, and promulgating them [Tornatzky et al., 2002].

- Universities must work towards strengthening their dissemination strategy and using elements of marketing for sharing research results, and their relevance in order to attract new partners. They should use a variety of channels to enhance the dissemination of results leading to improved industrial adoption of research such as increased contact with consumers of knowledge, validating the applicability of research results in a client-centric way, and formally creating new positions as knowledge brokers in academia.

- Communicate the value of research. Progress reports should be made available at various stages of collaboration. Communicating the benefits of a UIC can stimulate future collaborations.

7.4.7 Social Capital Practices

7.4.7.1 Adopt measures to increase trust and commitment

Collaboration partners need to adopt measures that help develop and support trust and commitment among them.

The existence of mutual trust is an important factor leading to more open communication and effective knowledge sharing between various stakeholders. Greater trust is also expected to increase confidence among partners, improve conflict resolution, allow more flexibility in relationships, and reduce control [Santoro and Bierly, 2006]. It contributes to the success of UIC.

Commitment, along with trust, is also a significant factor influencing the renewal of relationships between collaborators [Plewa and Quester, 2007]. Commitment refers to the dedication of an organization in terms of management support and resources allocated to UIC. Strong commitment by stakeholders is a key success factor for any collaboration [Plewa and Quester, 2007; Barnes et al., 2002; Santoro and Gopalakrishnan, 2001; American Association of State Colleges and Universities, 1987]. On the industry side, a strong commitment leading to a continued interest in projects during their development stages and in their results is a significant factor for fostering successful UIC [Mora-Valentin et al., 2004; Peças and Henriques, 2006; Barbolla and Corredera, 2009; Rahm et al., 2013]. High levels of commitment are expected to result in extensive participation from industry personnel in establishing research agendas followed by reviewing research progress and results.

Trust and commitment are interdependent and influence each other. Greater commitment leads to greater trust.

The following recommendations are part of this practice:

- 'Establish and nurture trusting working relationships between collaborators' [Strieter and Blalock, 2006].
- 'Create an environment of trust and transparency' [Rohrbeck and Arnold, 2009]. The importance of a trusting environment was also noted during the qualitative study described in Chapter 4. Trust was deemed necessary to encourage disclosure and discussion of ideas.
- Ensure that there is a commitment from industry in the form of resource allocation and involvement of managers with a clear definition of their roles in the UIC project [Peças and Henriques, 2006].
- Select and work on areas of interest of stakeholders in UIC, which increases commitment.

7.4.7.2 Ensure mutual obligations, and common understanding

Any successful relationship requires a positive attitude from partners, mutual respect and commitment to the collaborative venture [Dryden and Erzurumlu, 1996; Prigge, 2005]. In order to ensure a positive attitude and mutual respect from partners, it is important to pay due consideration during selection of partners and projects. Practices related to appropriate partner selection and collaboration project were discussed in Section 7.4.1 and Section 7.4.4 respectively. I have discussed practices related to common understanding in Section 7.4.3.

7.4.8 Legal Practices

7.4.8.1 Develop a common understanding of Intellectual Property

UIC partners should develop a common understanding of IP.

Intellectual property rights are an important factor in many UICs. The process of identifying possible IP, decisions to protect it, and patent portfolio management is challenging. All UIC stakeholders must develop a common understanding around Intellectual Property (IP).

The following recommendations are part of this practice:

- Clearly articulate information related to IP to improve understanding of IP.
- Information related to invention disclosure and the patenting process should be made available to staff to increase their understanding of various aspects associated with IP. For example, institutions demonstrating excellent technology transfer functions in a US study ensured 'extensive informational outreach to faculty members to familiarize them with principles and operations of the technology transfer function' [Tornatzky et al., 2002]. Such access to information and clear understanding will help overcome legal barriers associated with information availability.

7.4.8.2 Negotiate and clearly articulate intellectual property rights

UIC partners should negotiate intellectual property rights, and clearly articulate the agreed terms [Dollinger et al., 2018]. Intellectual property negotiations have been formidable barriers to forming effective UICs. In order to prevent IP from becoming a stumbling block, partners should minimize constraints on information and universities should not seek to over-protect IP.

The following recommendations are part of this practice:

- Establish shared and enforceable guidelines limiting disclosure restrictions, and limiting conflicts of interest [Burnside and Witkin, 2008; Santoro and Betts, 2002; Schofield, 2013; Valentín, 2000].

- Articulate clear policy regarding publication and IP rights after negotiation [Rohrbeck and Arnold, 2009; Potworowski, 1989].

- Establish a legal framework for the collaboration. For example, framework utilisation for negotiations has proven to be successful in the case of Hewlett Packard (HP) and UC Berkeley, which led to the adoption of a similar approach in another agreement negotiation between HP and UC Davis. [Burnside and Witkin, 2008].

- Design contracts that include exclusivity clauses. Consider providing IP rights, or the exclusive licensing right of UIC results to the industry stakeholders [Webster and Etzkowitz, 1991; Valentín, 2000] to build stronger relationships.

- Minimize constraints on information sharing [Valentín, 2000].

- Adopt more flexibility while negotiating agreements [Siegel et al., 2003c]. A study of universities, including US leaders in industry-sponsored research, indicates the importance of simplifying research contract language and using novel forms of packaging relationships (e.g., master agreements, strategic partnerships) [Tornatzky et al., 2002]. Another example is the new Intellectual Property and Industry Research Alliances office (IPIRA) established at the UC Berkeley. The IPIRA was established with an objective of streamlining relations with industry by acting as a 'one-stop shop' for UIC. It has led to faster contract negotiations with industry.

- Stakeholders must adopt a mature attitude to see the value of a UIC in terms of benefits other than just IP.

7.5 Application of the UIC Practices Framework

The proposed UIC Practices Framework can be used in conjunction with the Cynefin sense-making framework as part of the proposed UIC Framework, or as a standalone tool as described in the following sections.

7.5.1 Using the UIC Practices Framework with the Cynefin sense-making framework

- **Obvious Domain.** Within the obvious domain, the framework can be utilised to identify 'best' practices that can be used to ensure the effectiveness of UICs.

- **Complicated Domain.** Within the complicated domain, the framework can be utilised by experts to identify an appropriate set of practices that can be used to ensure the effectiveness of UICs.

- **Complex Domain.** Within the complex domain, experts can utilise the framework to design experiments to test the effectiveness of specific practices in a particular context. These experiments are expected to lead to emergence of new or best practices. As effective practices emerge, the UICs may move into the complicated domain, where experts can better manage them.

- **Chaotic Domain.** Within the chaotic domain, experts can select practices that they hope will immediately restore some kind of order and move the problem to the complex domain where more time can be used to find practices that are effective.

The detailed process for using the UIC Practices Framework within the UIC Framework is described in Chapter 9.

7.5.2 Using the UIC Practices Framework as a standalone tool

UIC stakeholders can use practices recommended by the proposed UIC Practices Framework to make informed decisions during the various stages of UICs. Better decisions will result in more effective UICs.

7.6 Evaluation of the UIC Practices Framework

As described in Chapter 3, a two-phase evaluation approach is adopted during this research. Phase one involves descriptive evaluation using illustrative scenarios, logical arguments, and expert evaluation. Section 9.3 in Chapter 9 presents scenarios that demonstrate the use of the UIC Practices Framework. These demonstrations also serve as descriptive evaluations of the UIC Practices Framework.

Phase two involves further validation to test the real-world utility and effectiveness of the framework, as detailed in Chapter 10.

7.7 Conclusion

In this chapter, a UIC Practices Framework is proposed to improve the effectiveness of UIC. The framework is based on a review of success factors and practices for collaboration described in existing literature as well as findings of the qualitative study involving industry practitioners and university researchers detailed in Chapter 4. As a consequence, the framework has its foundation in the existing literature as well as observations and experiences of the real-world.

During development of the framework an opportunity was identified to propose a new categorization scheme for success factors (Table 7.1) and practices (Table 7.2).

Often, the complex nature of the UIC process makes it difficult to guarantee success. However, the proposed practices framework is expected to improve the effectiveness of collaboration as it adopts a holistic view of collaboration and focuses on the success factors for, and barriers to UIC. It attempts to provide necessary guidelines for establishing and sustaining successful collaborations by providing a comprehensive and coherently integrated set of UIC practices that stakeholders can access in a single location.

By using this framework, universities and industries can establish a UIC, which is expected to be more effective and successful. It can be used alone or in conjunction with the Cynefin framework. While the framework includes practices for collaboration, it is not prescriptive. The practices are dynamic and may change with accumulation of knowledge and experience from use of the framework.

While the UIC Practices Framework focuses on universities and industry, it is expected to find wider applicability as the practices covered in the framework are based on general success factors and barriers that seem relevant to other contexts. Hence, the practices can be generalized to other organizational collaborations.

In order to assess the UIC maturity of an organisation on the basis of applied practices, a UIC Maturity Model is proposed in the next chapter.

Chapter 8

University-Industry Collaboration Maturity Model

In order to understand and improve University-Industry Collaboration (UIC), it is important for stakeholders to analyse and evaluate the state of their collaborative efforts. One way to conduct such assessment is by using maturity models, which have been applied successfully in many domains including software development, quality assurance, knowledge management, and business processes.

In this chapter, I propose the UIC Maturity Model (UICMM) - a collaboration maturity model based on the practices framework presented in Chapter 7, and existing maturity models relevant to collaborations. The UICMM is intended to be a useful benchmarking tool for a range of stakeholders including universities and industry to assess and benchmark their collaborative efforts. The underlying hypothesis while developing this maturity model is that a higher level of maturity indicates increased collaboration and improved outcomes.

8.1 Introduction

An organization engaged in collaboration would be interested in analyzing and evaluating the effectiveness of their collaborative efforts in order to identify and adopt improvements. A maturity model for collaboration can serve as a tool in assisting the planning of collaborations and evaluating their effectiveness. The use of maturity models is considered as a practical and widely accepted way for assessing organizations. In general, these models include progressive levels of maturity that can be achieved in a stepwise manner, allowing organizations to plan to achieve higher levels of maturity and evaluating their outcomes on achieving the planned levels.

A UIC Maturity Model (UICMM) is developed, which can be used by experts to

assess an organisation's level of UIC maturity and guide their improvements.

8.2 What is a Maturity Model?

In general, 'maturity' can be defined as 'the state of being complete, perfect or ready' [Simpson et al., 1989]. That state is achieved through the transition of an entity from an initial level of maturity to a more advanced level, through intermediate levels. Thus, maturity implies evolutionary progress through a series of maturity levels. Maturity models provide a framework to describe and achieve such evolutionary progress.

The concept of maturity models originated in the early 1980s at IBM when Watts Humphrey and his colleagues noticed a positive correlation between the quality of the processes followed during software development and the quality of the software developed. It was observed that process improvement is evident as a series of steps. Humphrey [Humphrey, 1989] took his ideas to the Software Engineering Institute (SEI) at Carnegie Mellon University, where the maturity model framework was formulated [Paulk, 2009]. The term 'maturity model' was introduced and popularized by the SEI with development of the Capability Maturity Model (CMM) [Paulk, 2009; Chrissis et al., 1995] that later evolved into the CMM Integration (CMMI) [Chrissis et al., 2003]. These models were developed to assess the maturity or capability of software development processes in organizations.

Thus, a Maturity model is a tool used to assess and improve maturity of an organization's capabilities in a particular area of operation. They can be used:

- to evaluate and compare an organization's current situation,
- to identify 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 improvement action [Becker et al., 2009; Hain, 2010; Hain and Back, 2011].

The underlying idea of any maturity model is that organisations operating at higher levels of maturity are likely to be conducting the subject activity (eg. software engineering) more successfully. So, organisations working at higher levels of the UICMM are likely to be undertaking more effective and successful UICs. That is, a maturity model is a kind of proxy for direct evaluation of the output of a target activity. For example, use of the CMM is a proxy for evaluating the quality of software

produced by a software engineering process. Those operating at higher levels of the CMM are likely to be producing higher quality software. So if we evaluate an organisation at low levels of the UICMM, they are unlikely to be engaging in effective UICs. Those at higher levels of maturity, are likely to be engaging in successful UICs. So, use of the UICMM is a proposed 'approach' to evaluating UICs within the context of a given organization. Moving up the maturity levels, implies 'improvement' of UICs undertaken by the organisation.

8.2.1 Maturity Model Structure

Fraser [Fraser et al., 2002] identified the following basic components of maturity models:

- 'a number of levels (typically three to six),
- a descriptor for each level (such as the CMM's differentiation between initial, repeatable, defined, managed, and optimising processes),
- a generic description or summary of the characteristics of each level as a whole,
- a number of dimensions (often referred to as Key Process Areas),
- a number of elements or activities for each dimension, and
- a description of each element or activity as it might be performed at each level of maturity.'

8.3 Existing Maturity Models

In this section existing Maturity Models across a number of domains are reviewed. I consider these maturity models in order to deepen understanding of the various maturity models existing in literature, and to inform development of the proposed UICMM.

Maturity Models in the domains of knowledge management, and interoperability are considered as these domains are closely related to collaboration, and can play a significant role in improving its effectiveness.

I then look, in detail, at Maturity Models that specifically deal with various forms of collaboration.

One of the earliest documented Maturity Models is Crosby's Quality Management Maturity Grid (QMMG) [Crosby, 1979] that was developed for the purpose of evaluating the status and development of a firm's quality management approach.

In the area of software engineering processes, the Capability Maturity Model (CMM) has been proposed as an attempt to guide software organizations in enhancing software quality [Chrissis et al., 1995]. The CMM is intended to determine the current process maturity, guide the selection of process improvement strategies, and identification of the most critical areas for improvement of software quality and processes by software organizations. The model has gained considerable acceptance worldwide and has been regarded by many as the industry standard for defining software quality process [Paulk, 2009; Herbsleb et al., 1997; van der Pijl et al., 1997]. In the CMM, five levels of maturity are defined, namely initial, repeatable, defined, managed, and optimizing. Each maturity level is described by a unique set of characteristics that should be demonstrated by an organisation at a particular level.

With the integration of systems engineering, software engineering, and integrated process and product development, CMM evolved into CMM Integration (CMMI) [Paulk, 2009]. According to the SEI, CMMI helps 'integrate traditionally separate organizational functions, set process improvement goals and priorities, provide guidance for quality processes, and provide a point of reference for appraising current processes.'

Various maturity models have also been proposed in the knowledge management (KM) domain. Paulzen and Perc proposed a Knowledge Process Quality Model (KPQM) based on the ideas of quality management and process engineering [Paulzen et al., 2002]. A General Knowledge Management Maturity Model (G-KMMM) [Teah et al., 2006], based on the review, comparison and integration of existing Knowledge Management Maturity Models (KMMM), assesses the maturity of people, process and technology aspects of KM development in organizations.

In the domain of interoperability, a few maturity models have been proposed [Clark and Jones, 1999; Van Staden and Mbale, 2012] and reviewed [Guédria et al., 2008]. Levels of Information System Interoperability (LISI) [C4ISR Architecture Working Group and others, 1998] is a widely recognized model for system of systems interoperability. The main focus of LISI is on technical interoperability and interoperational complexity between systems. Other models include Organizational Interoperability Maturity Model [Clark and Jones, 1999], NATO C3 Technical Architecture (NC3TA) Reference Model for Interoperability, Levels of Conceptual Interoperability (LCIM) Model, Layers of Coalition Interoperability, and The System of Systems Interoperability (SOSI) Model [Morris et al., 2004]. Gottschalk proposed a maturity model for interoperability in digital government focusing on interoperability of system, process, knowledge, value, and goal [Gottschalk, 2009].

In addition to Maturity Models developed in technical domains such as software engineering, knowledge management, and interoperability, they have also been

developed in domains such as security, user experience, customer service, project management, health care, learning, marketing, analytics, risk and fraud.

The existence of such vast number of maturity models in a diversity of areas as described above indicates their wide acceptance, use and value as an assessment tool.

8.3.1 Existing Collaboration Maturity Models

In this section, I review various maturity models proposed for improving collaboration. These models are described below and summarized, along with their associated KPAs, in the Table 8.1. While the list of models is not exhaustive, it is representative of relevant maturity models.

8.3.1.1 Collaboration Maturity Grid (CMG)

The Collaboration Maturity Grid (CMG) [Fraser et al., 2003] is used to examine the issues faced by organisations during outsourcing activities, and provide guidance to managers involved in collaborations.

The CMG is based on a review of new product introduction (NPI) literature, a qualitative study involving practitioners, and case studies of firm-firm collaboration. Feedback from practitioners during the development of the model adds relevance to it and increases its potential application.

The model considers the complete lifecycle of a collaborative development project with the mapping of relevant factors at each phase of the lifecycle. It identifies the following seven 'Key Process Areas' and defines criteria associated with them at each maturity level.

- 'collaboration strategy,
- structured development process,
- system design and task partitioning,
- partner selection,
- project initiation,
- partnership management, and
- partnership development'.

The model has proven to be useful through field-testing in inter-firm collaboration contexts.

8.3.1.2 Crowdsourcing Ideation Maturity Assessment Model (CIMAM)

The Crowdsourcing Ideation Maturity Assessment Model (CIMAM) [Boughzala et al., 2014] is a maturity model for the assessment of ideation processes in crowdsourcing projects. It can assist organizations in the selection of effective crowdsourcing platforms, determining the most suitable idea, and managing evaluation practices for selected projects.

The CIMAM is based on a literature review of maturity models, crowdsourcing, and a conceptual model for crowdsourcing [Pedersen et al., 2013]. Its development follows the Design Science approach. The model defines six KPAs, referred to in the model as 'themes' (adapted from [Pedersen et al., 2013]), as depicted in Table 8.1. For each KPA, the model identifies the criteria that must be met to achieve each level of maturity.

Unlike other collaboration maturity models discussed in this section, the CIMAM places a strong emphasis on technology as crowdsourcing can not be operated without a digital platform. The process of application of the model is documented and it has been validated against Hevner's design science guidelines [Hevner et al., 2004]. While the model considers collaboration, its application is limited to crowdsourcing.

8.3.1.3 Collaboration Maturity Model (Col-MM)

The Collaboration Maturity Model (Col-MM) [Boughzala and de Vreede, 2012] is proposed for assessing an organization's team collaboration quality. It is generic-enough to be applied to any type of collaboration, and can be used by practitioners for self-assessments.

The development of Col-MM, like CIMAM, is based on the Design Science approach. It involved engagement with a focus group of professional collaboration experts, which contributed to increased relevance and applicability of the resulting model. The model defines the same levels of maturity as the CIMAM, and is one of the most comprehensive models in terms of the various KPAs of collaboration covered. These KPAs, referred to in the model as 'areas of concern', are based on the suggestions of experts, making them relevant to practice. The model clearly articulates the criteria associated with each KPA with their descriptions indicating an evolutionary progress from lower levels to higher levels of maturity. The process for application of the model is well-documented and it has been validated in real-world settings.

8.3.1.4 Enterprise Collaboration Maturity Model (ECMM)

The Enterprise Collaboration Maturity Model (ECMM) presents a process improvement approach for organizations participating in a collaborative network. A collaborative network comprises of geographically distributed and usually heterogeneous organizations collaborating over a digital network to achieve a common goal [Camarinha-Matos et al., 2009].

The model is used to assess organizations participating in a network, both as a stand-alone company and with respect to the network [Alonso et al., 2010]. The results of this assessment provide organizations with their current state of collaboration, the requirements they are expected to satisfy in order to reach the next level of maturity, as well as a roadmap and improvement plan for doing so.

The structure of ECMM is based on CMMI building blocks. The model defines seven KPAs, referred to as 'domains' in the model, and further identifies an exhaustive list of more specific process areas within each KPA. However, the characteristics of the KPAs at each level of maturity are not described, which may lead to difficulty in assessing the maturity level of an organisation. On a positive note, the process of application of the model is clearly documented.

8.3.1.5 Collaboration Engineering Maturity Model (CEMM)

Collaboration Engineering is an approach to the design and deployment of collaborative processes [Briggs et al., 2003; Kolfschoten and De Vreede, 2009].

The Collaboration Engineering Maturity Model (CEMM) was proposed to help improve Collaboration Engineering (CE) processes. The approach has two dimensions: the phases of the collaboration engineering approach and the maturity levels corresponding to each phase [Santanen et al., 2006]. The model assists with monitoring and assessment of Collaboration Engineering processes.

Regarding development of the CEMM, it is derived from the Software Process Improvement and Capability dEtermination (SPICE) model [ISO/IEC, 2004]. If we analyse the design of the maturity model, it focuses on the various phases of collaboration. Unlike other maturity models, it uses these phases for maturity level assessment instead of associating any Key Process Areas with the maturity levels.

Table 8.1: Collaboration Models in the Existing Literature

Model	Levels	Key Process Areas (KPAs)	Inspiration	Context
CMG	4 levels: Level 1, Level 2, Level 3, and Level 4	collaboration strategy, structured development process, system design and task partitioning, partner selection, project initiation, partnership management and partnership development.	CMMI, KMMM and BPMM	Outsourcing, Distributed Development
CIMAM	4 levels: Ad-hoc, Exploring, Managing, and Optimizing	Problem, Process, Governance, People (Crowd, Individual, Problem owner), Technology, Outcome	Maturity Model literature	CrowdSourcing
Col-MM	4 levels: Ad-hoc, Exploring, Managing, and Optimizing	Collaboration characteristics, Collaboration Management, Collaboration Process, Information and Knowledge Integration	Maturity Model literature and Focus Group	Team collaboration in an organization
ECMM	4 levels: Performed, Managed, Standardized, and Innovating	Project and Product Management, Business Process and Strategy, Customer Management, Collaboration, Legal Environment and Trust, Organisation, Systems and Technology, Innovation	CMMI	Business in a networked environment
CEMM	4 levels: Provisional, Predictable, Managed, and Optimized	Phases of Collaboration Engineering	Maturity Model literature	Collaboration Engineering Processes
CollabMM	4 levels: Ad-hoc, Planned, Aware, and Reflexive	Communication, coordination, group memory and awareness	CMMI, KMMM and BPMM	Team collaboration within an organization.
DPMM	3 levels: initiation, consolidation, and high-productivity	Belief and willingness , Personnel communication skills, Utilization of distributed technology infrastructure, Critical mass (team size), Understanding cultural differences, Managerial training, Setting shared business goals, Tailoring business goals, Budgeting and cost structures, Devising mechanisms for division of labor, Product development tools and processes, Consistency in project management processes, Ownership and responsibilities, Knowledge transfer, Top-management communication channels, Performance monitoring, Managing complexity, Managing social networks, Enabling social communication via technology, Nurturing and leveraging core competencies, Interorganizational innovation management, Best practices management, Contract management and nurturing partnership, Managing symbiotic relationship and continuous development	CMMI, KMMM and BPMM	Distributed Development

8.3.1.6 Collaboration Maturity Model (CollabMM)

The Collaboration Maturity Model (CollabMM) was inspired by existing maturity models such as CMMI, KMMM and Business Process Maturity Model (BPMM) [Rosemann et al., 2004], and aims to organize a set of practices for enhancing collaboration in business processes [Magdaleno et al., 2009, 2011].

The CollabMM is defined based on four KPAs: communication, coordination, awareness, and memory, which were identified through a review of groupware research literature. The activities associated with these KPAs at each maturity level are defined. However, the activities need clear articulation for each maturity level to indicate their evolutionary progress. It is acknowledged by the authors of the model that the levels definitions and the measurements of each level need to be formalized. The model has been applied in two organizations and the limitations identified during the application of the model led to the identification of a roadmap for its evolution [Magdaleno et al., 2011].

8.3.1.7 Distributed Process-Maturity Model (DPMM)

The Distributed Process-Maturity Model [Ramasubbu et al., 2005] has 3 levels of maturity, and features 24 KPAs mapped to four concepts for distributed development: mutual knowledge, technology readiness, collaboration readiness, and coupling in work (mechanisms for division of labour).

Development of the DPMM has a theoretical grounding in existing literature related to distributed development. Its development was driven by the requirement to evaluate the performance of distributed development, limitations of the CMM and ISO 9001 to conduct such assessment, and the need to identify best practices for improving performance in the context of its application.

Similar to the CIMAM [Boughzala et al., 2014], the DPMM emphasises use of technology, which is an essential factor for distributed development. Unlike other collaboration maturity models, the DPMM places the KPAs themselves at different levels of maturity instead of defining evolutionary progress of characteristics for KPAs. For example, the concept 'coupling in work' does not have a KPA defined at level 1.

The model has been validated using expert evaluation and data collection from real-world projects.

Table 8.2: Key Process Areas (KPAs) of UICMM in relation to KPAs of other Maturity Models

UICMM	CMG	CIMAM	Col-MM	ECMM
Contextual	Partner selection		Collaboration characteristics	Collaborative customer relationship management, Customer evaluation, Open innovation
Organizational	Collaboration strategy	Governance Technology	Collaboration characteristics	Business management Measurement analysis Resource management Organization innovation Training and competency development Organizational process performance
Cultural adaptation				
Operation and Management	Project initiation Structured development process System Design and Task Partitioning	Problem Process Governance	Collaboration characteristics	Collaborative project management Configuration management Process and Product assurance Requirements management Business governance Collaborative business process Defect and problem prevention Requirements development Risk management Technical solution Quantitative project management
Individuals		People	Collaboration characteristics	
Communication	Partnership management	Technology	Collaboration characteristics	Interoperability and Collaboration technologies
Social Capital	Partnership development	People	Collaboration characteristics	Trust management
Legal	Project initiation			Collaboration agreement, IPR
Outcome		Outcome		
Knowledge Management		Technology	Information and knowledge integration	

Table 8.3: Key Process Areas (KPAs) of UICMM in relation to KPAs of other Maturity Models

UICMM	CEMM	CollabMM	DPMM
Contextual	Field interview	Awareness	Belief and willingness
Organizational	Sustained organizational use		Belief and willingness Utilization of distributed technology infrastructure Budget and cost structure Managerial training Nurturing and leveraging core competencies Best practices management
Cultural adaptation		Coordination	Understanding cultural differences
Operation and Management	Field interview Design Transition Practitioner implementation		Setting shared business goals Tailoring business goals Devising mechanism for division of labour Product development tools and processes Consistency in project management processes Ownership and responsibilities Performance monitoring Managing complexity
Individuals			Personnel communication skills Critical mass Managing social networks
Communication		Communication	Top-management communication channels Enabling social communication
Social Capital			Managing symbiotic relationship and continuous development
Legal			Contract management and nurturing partnership Interorganizational innovation management
Outcome			
Knowledge Management		Memory	Knowledge transfer

8.3.2 The need for a new Maturity Model for UIC

As illustrated in the previous section (Section 8.3.1), various models for collaboration have been proposed in the existing literature. All of these maturity models have defined a set of maturity levels along with associated KPAs. They generally have 4 levels except for DPMM [Ramasubbu et al., 2005], which has 3 levels, as depicted in Table 8.1. Most of the models have levels indicating progress from 'ad-hoc' to 'optimized', though different terminologies have been used.

Tables 8.2 and 8.3 show the KPAs covered by the maturity models discussed in Section 8.3.1. These KPAs are grouped according to the KPAs to be used by the proposed UICMM described in Section 8.4. These UICMM KPAs are those applicable to UIC and were derived from the categorization of practices presented in Chapter 7, and KPAs common across the maturity models discussed in Section 8.3.1.

Tables 8.2 and 8.3 show that none of the existing models cover all of the KPAs applicable to UIC. Most of the KPAs in the Collaboration Maturity Grid (CMG) [Fraser et al., 2003] are relevant to UIC. However, its focus on NPI and inter-firm collaboration may restrict its generalization to UICs, which do not always involve or lead to creation of a product. The CIMAM [Boughzala et al., 2014] focuses on crowdsourcing. Crowdsourcing is open collaboration. In contrast, in a UIC, university and industry participants have to work under the guidelines or code of conduct of their organizations. Hence, crowdsourcing operates in a different professional environment compared to formal UICs. So, application of the CIMAM to UIC needs validation. The Col-MM [Boughzala and de Vreede, 2012] is limited to assessing team collaboration quality within an organization. While aspects identified in the CollabMM are relevant to UIC, the model has been designed for the intra-organisational setting, and does not consider several aspects relevant to UIC such as cultural adaptation, and organizational factors. The DPMM considers a comprehensive set of factors for distributed software development, which are also relevant to UIC. However, globally distributed development teams may be operating within a single organisation. As such, they may have fewer conflicts arising out of different operational cultures. Hence, application of the DPMM to UIC, which involves multiple organisations with different operational norms, would need to be the subject of further research.

The above analysis demonstrates the need and scope for developing a comprehensive UIC maturity model. In order to address this need, the UICMM, a comprehensive maturity model for assessing organizational collaboration maturity, is proposed based on the UIC Practices Framework (Chapter 7) and existing relevant maturity models.

8.4 UICMM: A Maturity Model for University-Industry Collaboration

In this section I describe the UICMM along with the methodology adopted to develop and evaluate it.

8.4.1 UICMM Design

Because maturity models are artefacts designed to solve particular problems, Design Science, as described in Chapter 3, will be used to design and evaluate the UICMM. Specifically, Becker's [Becker et al., 2009] systematic approach for developing maturity models based on Design Science guidelines defined by Hevner et al. [Hevner et al., 2004] will be adopted.

Becker's approach comprises a set of eight requirements, which need to be addressed when designing a new Maturity Model. Each of the following sections describe the design of the UICMM in terms of these requirements.

8.4.1.1 R1: Comparison with existing maturity models

> *'The need for the development of a new maturity model must be substantiated by a comparison with existing models. The new model may also just be an improvement of an already existing one.'*

I have reviewed the existing maturity models and compared the models related to collaboration as depicted in the Table 8.1. None of these models specifically address UIC, but they do provide guidance in identifying key process areas for the UICMM.

8.4.1.2 R2: Iterative Procedure

> *'Maturity models must be developed iteratively, i. e., step by step.'*

An iterative procedure was followed to develop the initial version of the UICMM. The first model was developed based on the UIC Practices Framework described in Chapter 7. This model was further developed using inputs from the review of existing maturity models presented in Section 8.3.1. As lessons are learned during real-world evaluation and use of the UICMM (Chapter 10), I expect to create further iterations of the model.

8.4.1.3 R3: Evaluation

> *' All principles and premises for the development of a maturity model, as well as usefulness, quality and effectiveness of the artifact, must be evaluated iteratively.'*

The proposed maturity model has been evaluated against the general requirements of a maturity model outlined in literature [Fraser et al., 2002; Klimko, 2001] as described in Section 8.6.1. An evaluation for utility and applicability of UICMM is presented in Section 8.6.2. In addition, I have developed a strategy for real-world evaluation and improvement of the model as described in Chapter 10.

8.4.1.4 R4: Multi-methodological Procedure

> *'The development of maturity models employs a variety of research methods, the use of which needs to be well-founded and finely attuned. This requirement is based on 'Guideline 5: Research Rigor', that recommends that the selected methods need to be rigorously attuned.'*

This requirement is fulfilled by using various methods for data-collection to develop the model such as the qualitative study described in Chapter 4, the UIC Practices Framework described in Chapter 7, and review of existing maturity models as described in Sections 8.3.1 and 8.4.1.1 (R1).

8.4.1.5 R5: Identification of Problem Relevance

> *'[Design Science] 'Guideline 2: Problem Relevance' [Hevner et al., 2004] states that the problem-solving artifact must not only be innovative, but the problem to be solved must also be relevant for researchers and/or practitioners. This relevance can again be established through different scientific methods, e. g. by interviewing potential users of the maturity model in question. Establishing relevance also requires the exact definition of the problem, which in turn is prerequisite for ensuing evaluations. The relevance of the problem solution proposed by the projected maturity model for researchers and/or practitioners must be demonstrated.'*

The work presented in Chapter 2 and Chapter 4 as well as the early feedback from the potential users (Section 8.6.2), establishes the relevance of the problem, and importance of this work.

8.4.1.6 R6: Problem Definition

> *'The prospective application domain of the maturity model, as well as the conditions for its application and the intended benefits, must be determined prior to design.'*

The problem has been clearly defined in Chapter 1 as 'the need to improve UIC'. The objective is identified as evaluating and improving UIC. The UICMM presents itself as a tool to assist organisations in assessing their UIC maturity. The UICMM can be applied in both inter-organisational and intra-organisational settings. The intended benefits of using the UICMM include improved UICs which will, in turn, deliver benefits to both industry and universities as discussed in Section 2.2.

8.4.1.7 R7: Targeted Presentation of Results

> *'The presentation of the maturity model must be targeted with regard to the conditions of its application and the needs of its users. Documentation of the research process is of vital importance for the scientific procedure. 'Guideline 7: Communication of Research' emphasizes that the presentation of results must be targeted at the specific user groups.'*

The UICMM has been presented using KPAs relevant to UICs. The characteristics of KPAS have been described for each level of maturity to assist in assessment of the evolutionary progress of an organisation's UIC maturity. In addition, the process of application of the UICMM as well as a survey questionnaire to assist the assessment is documented in this thesis. It is expected to be useful for various stakeholders in UIC. Further, a digital tool designed to support UICMM based assessments and presentation of assessment results, is planned as part of future work (Chapter 11, Section 11.7). The research process adopted during development of the UICMM is clearly documented.

8.4.1.8 R8: Scientific Documentation

> *'The design process of the maturity model needs to be documented in detail, considering each step of the process, the parties involved, the applied methods, and the results. [Becker et al., 2009]'*

Documentation of the UICMM development is presented in this thesis. The definition of each maturity level has been clearly documented for understanding and

application by its intended users. In addition, a conference paper related to this work has been published [Awasthy et al., 2018], and submission of an extended version has been requested for publication in a journal.

8.4.2 UICMM Maturity Levels

The proposed UICMM comprises five levels of maturity as depicted in Table 8.4 and described below.

Table 8.4: Maturity Levels of UICMM

Level	Definition
5: Continuous improvement	Continual improvement. Diversity of stakeholders. Collaboration processes are reviewed, measured and improved.
4: Practised and Managed	Ensuring the quality of both the collaboration process and outcomes. Collaboration related activities are part of work-flow with commitment from leadership, and training and rewards for individuals engaging in collaboration.
3: Encouraged	Culture encourages collaboration. Value of collaboration is recognized. Awareness of various ways of interaction. Clear objectives for collaboration.
2: Initial	Awareness of value of collaboration leads to efforts to gain knowledge about various ways of collaboration. People who understand the value of collaboration may do it.
1: Non-existent	Isolated entities. There is general unwillingness to collaborate. Collaboration is not valued.

Level 1: Non-existent - At this level, organisations work as isolated entities. Collaboration is not initiated or conceptualised due to a general unwillingness to collaborate. There is lack of recognition of its value. This level recognizes that some organisations may not be currently engaging in UIC.

Level 2: Initial - Organisations are developing awareness of the collaboration system, which means they are spending time researching emerging collaborations among other organisations. At this level organisations are realizing the importance of collaboration and are initiating efforts to collaborate. They gain knowledge regarding various ways of collaboration. Motivation and benefits of collaborations are identified. Various barriers to collaboration are studied and understood. However, organisations are still thinking in isolation and are working towards their own distinct goals with independent decision-making.

Level 3: Encouraged - Organizational culture encourages collaboration as its value is recognized. At this level, stakeholders have been identified, objectives are defined and a framework to work under has been agreed upon. This level is focused on the structure and definition of processes involved in collaboration. Processes are customized in order to achieve shared objectives among stakeholders.

Level 4: Practised and managed - Value of collaboration is well-established with quality of both the collaboration process and outcomes being ensured. Goals are shared by collaborators and progress is tracked. To enhance the effectiveness of collaboration there are defined processes for collaboration. Training is provided to individuals engaging in collaboration. Systems/tools are set-up for collaboration, and performance is measured. Leadership exhibits commitment to collaboration and provides a collaboration strategy.

Level 5: Continuous improvement - This is the level of continual improvement, where collaboration is mature and operating seamlessly between a diverse set of stakeholders. It is achieving high quality outcomes and deriving benefits that have a wider socio-economic impact. Collaboration systems are widely accepted, monitored and updated accordingly. Review processes are established to assess collaboration processes and feedback into the system for continuous improvement. Past experiences are utilized to make informed decisions. Collaboration assessment guides realistic improvements by identifying improvement areas.

8.4.3 UICMM Key Process Areas

The dimensions or Key Process Areas (KPAs) in a maturity model indicate the areas where organisations should focus in order to improve the maturity of the subject domain such as quality assurance, interoperability, UIC. To be specific, the SEI defines a process area as 'a cluster of related practices in an area that, when implemented collectively, satisfies a set of goals considered important for making improvement in that area' [CMMI Product Team, 2011, pg. 13].

In the UICMM context, KPAs indicate the identified areas where organizations should focus in order to improve the effectiveness of UIC by achieving higher levels of maturity. Descriptions of practices associated with the KPAs at each level will allow organisations to assess their current level of maturity and identify the practices to be followed or improved to achieve higher levels of UIC maturity.

The following Key Process Areas (KPA) of the UICMM are derived from the UIC Practices Framework (Chapter 7) and existing maturity models (Section 8.3.1):

- **Contextual** - related practices described in section 7.4.1.
- **Organizational** - related practices described in section 7.4.2.
- **Cultural adaptation** - related practices described in section 7.4.3.
- **Operation and Management** - related practices described in section 7.4.4.
- **Personnel** - related practices described in section 7.4.5.
- **Communication** - related practices described in section 7.4.6.
- **Social capital** - related practices described in section 7.4.7.
- **Legal** - related practices described in section 7.4.8.
- **Outcome** - derived from the CIMAM [Boughzala et al., 2014] (section 8.3). Outcomes are the results of UIC for individuals and organisations, which may be direct or indirect, tangible or intangible, and positive or negative.
- **Knowledge Management** - derived from the CIMAM [Boughzala et al., 2014], Col-MM [Boughzala and de Vreede, 2012], ColabMM [Magdaleno et al., 2009], DPMM [Ramasubbu et al., 2005], and G-KMMM [Teah et al., 2006] (section 8.3). Knowledge management refers to the capacity of an organisation to manage its knowledge base including both tacit and explicit knowledge. It includes effective utilization of existing knowledge, and acquisition and absorption of new related and unrelated knowledge to achieve organizational goals.

The characteristics of KPAs at each level of the proposed UICMM are presented in Tables 8.5, 8.6, 8.7, 8.8, and 8.9. Descriptions of the characteristics have been derived from the UIC Practices Framework (Chapter 7) and characteristics of the maturity models reviewed in Section 8.3. These descriptions are intended to indicate incremental development in the KPAs as organizations increase their level of maturity. It is to be noted that the definition of characteristics of a KPA at each level is expected to include the characteristics at lower levels.

Table 8.5: Characteristics of Key Process Areas (KPAs) at Maturity Level 1 of UICMM

Maturity Level	**Key Process Areas**	**Description of Characteristics**
Level 1: Non-existent	Contextual (Practices in section 7.4.1)	Undefined.
	Organizational (Practices in section 7.4.2)	Unaware of collaboration needs.
	Cultural adaptation (Practices in section 7.4.3)	Difference in goals and objectives.
	Operation and Management (Practices in section 7.4.4)	No formal process to collaborate.
	Personnel (Practices in section 7.4.5)	Working in isolation. Not aware of the need to collaborate.
	Communication (Practices in section 7.4.6)	No communication.
	Social Capital (Practices in section 7.4.7)	Non existent.
	Legal (Practices in section 7.4.8)	Not applicable.
	Outcome	Unclear
	Knowledge Management	No management.

Table 8.6: Characteristics of Key Process Areas (KPAs) at Maturity Level 2 of UICMM

Maturity Level	Key Process Areas	Description of Characteristics
Level 2: Initial.	Contextual (Practices in section 7.4.1)	Efforts to understand the variety of possible UICs types, and identify motivations. No set process or criteria for identification of stakeholders.
	Organizational (Practices in section 7.4.2)	Understanding of the value of collaboration. No concern for Alumni relationships.
	Cultural adaptation (Practices in section 7.4.3)	Developing understanding of difference in culture, mission and goals between partner organisations.
	Operation and Management (Practices in section 7.4.4)	Identifying objectives and goals.
	Personnel (Practices in section 7.4.5)	Motivated to collaborate. Identification of key individuals.
	Communication (Practices in section 7.4.6)	Limited one way communication. Information is only provided when requested.
	Social Capital (Practices in section 7.4.7)	There is trust regarding ethical performance of partners. Commitment specific to the collaborative effort. Trust needs to be established beyond individual UICs.
	Legal (Practices in section 7.4.8)	Developing understanding regarding legal aspects including IP.
	Outcome	Some idea about goals.
	Knowledge Management	Limited knowledge sharing.

Table 8.7: Characteristics of Key Process Areas (KPAs) at Maturity Level 3 of UICMM

Maturity Level	Key Process Areas	Description of Characteristics
Level 3: Encouraged.	Contextual (Practices in section 7.4.1)	Variety of UIC mechanisms explored. Clear articulation of motivation. Predefined criteria for identification of stakeholders.
	Organizational (Practices in section 7.4.2)	Practices adopted to encourage collaboration. Short-term or lower levels of engagements. Alumni relationships encouraged.
	Cultural adaptation (Practices in section 7.4.3)	Creation of shared goals. Awareness of time requirements.
	Operation and Management (Practices in section 7.4.4)	Processes for collaboration formalized.
	Personnel (Practices in section 7.4.5)	Capable people to identify collaboration opportunities, reach out and engage.
	Communication (Practices in section 7.4.6)	Regularly scheduled communication. Two-way exchange.
	Social Capital (Practices in section 7.4.7)	Partner is considered as trusted, generally based on past experiences. Low commitment of time or resources.
	Legal (Practices in section 7.4.8)	Shared and enforceable guidelines established.
	Outcome	Clear definition of goals.
	Knowledge Management	Organization recognizes the importance of knowledge management. Basic knowledge management infrastructure established.

Table 8.8: Characteristics of Key Process Areas (KPAs) at Maturity Level 4 of UICMM

Maturity Level	Key Process Areas	Description of Characteristics
Level 4: Practised and Managed.	Contextual (Practices in section 7.4.1)	A portfolio of UICs is maintained. Precisely defined and organizationally aligned motivations. Defined process for identification of stakeholders.
	Organizational (Practices in section 7.4.2)	Collaboration is part of the organisation's strategy. Measures adopted to facilitate effective collaboration. Deeper levels of collaboration. Well-maintained alumni relationships.
	Cultural adaptation (Practices in section 7.4.3)	Common vision. Adapting to each other's requirements.
	Operation and Management (Practices in section 7.4.4)	Quantitative measurement of collaborations.
	Personnel (Practices in section 7.4.5)	Individuals recognize the value of collaboration. Individuals are trained. Self-motivated to engage in various collaborative efforts.
	Communication (Practices in section 7.4.6)	Planned as a part of collaboration. Systematic and multiple modes of communication. Balanced two-way exchange.
	Social Capital (Practices in section 7.4.7)	Complete trust among partners due to previous experiences. High commitment in terms of time or resources.
	Legal (Practices in section 7.4.8)	Clear and agreed IP and publication rights strategy.
	Outcome	Mutually beneficial outcomes aligned with goals. A broad spectrum of outcomes.
	Knowledge Management	Knowledge management is part of the organizational strategy.

Table 8.9: Characteristics of Key Process Areas (KPAs) at Maturity Level 5 of UICMM

Maturity Level	Key Process Areas	Description of Characteristics
Level 5: Continuous improvement.	Contextual (Practices in section 7.4.1)	Multiple types of collaboration. Shared motivation having wide impact. Informed identification and review of stakeholders.
	Organizational (Practices in section 7.4.2)	Collaborative efforts are measured and rewarded. Deeper and longer term collaborative engagements. Improvement measures for alumni relationships.
	Cultural adaptation (Practices in section 7.4.3)	Working seamlessly with each other.
	Operation and Management (Practices in section 7.4.4)	Collaboration processes are reviewed and improvement measures adopted. Existing processes can be adapted to address the requirements of changing environment.
	Personnel (Practices in section 7.4.5)	Boundary spanners are appointed. Leadership is involved and inspires individuals to collaborate.
	Communication (Practices in section 7.4.6)	Seamless communication. Communication of progress. Wider results dissemination methods.
	Social Capital (Practices in section 7.4.7)	Stronger trust leading to continued engagement. High commitment demonstrated through resource engagement and leadership involvement. There is continuous mutual improvement in trust and commitment between stakeholders.
	Legal (Practices in section 7.4.8)	Understanding of the value of partnerships beyond the IP rights. Review of strategies.
	Outcome	Collaboration is measured and reviewed based on outcomes.
	Knowledge Management	Knowledge management processes are reviewed for improvements.

8.5 Application of the UICMM

The proposed UICMM can be used in conjunction with the Cynefin sense-making framework as part of the proposed UIC Framework, or as a standalone tool as described in the following sections.

8.5.1 Using the UICMM with the Cynefin sense-making Framework

The proposed UICMM can be used in conjunction with existing organizational practices or, where applicable, in conjunction with the UIC Practices Framework (Chapter 7) and the Cynefin framework as described in Chapter 9. While the UICMM could be used in any Cynefin domain to assess the maturity level of UIC within an organization, it is most applicable in the complicated and complex domains.

In the complicated domain, experts can use the maturity model to identify and apply the practices required to move to the next level of maturity. Within the complex domain, experts can design experiments aimed at identifying those practices that will be effective in moving an organization to higher levels of maturity.

The detailed process for using the UICMM within the Cynefin framework is described in Chapter 9.

8.5.2 Using the UICMM as a standalone tool

In this section, I present a process for application of the proposed UICMM as a standalone tool in real-world settings. The process includes interviewing stakeholders, a survey instrument, and a review of information available through public sources.

The steps in the process are summarised below.

1. **Identify the unit of analysis for UICMM.** The UICMM was developed with an intention to assess the UIC maturity of organisations. The unit of analysis for evaluation of the UICMM is identified as an organisation. However, the assessment of an organisation cannot be conducted in isolation from the UIC projects it is engaging in. So, in order to assess the organisational UIC maturity, it is important to identify the UICs that will be included as part of the maturity level assessment.

   It is to be noted that the UICMM can be used for self-assessment or third-party assessment. In this step, this assessment type needs to be clearly stated. The self-assessment process may introduce some bias in the assessment. In order to overcome this bias, an evidence-based approach is recommended during infor-

mation gathering, where each criterion (characteristic of a KPA) is supported by evidence.

2. **Finalise information details.** This step involves identification of information to be gathered for the assessment purpose. The information includes organisational and project characteristics aligning with KPAs in the UICMM (Section 8.4.3).

3. **Identify the Participants.** This step identifies individuals to be involved in the information gathering process. The organisation will need to recommend individuals to be involved in the data-collection process based on the following criteria:

    * The individual possesses in-depth knowledge about UIC and/or maturity models.
    * The individual has experience through direct or indirect engagement in UIC within the organization.
    * The individual has access to required information within the organization
    * The individual has knowledge about the confidentiality of data being collected.
    * The individual has decision-making roles or authority to reach out to appropriate individuals within the organisation when seeking further information or clarification.

    To prevent data-collection bias, multiple individuals from diverse backgrounds representing different disciplines/sectors, such as project/department heads, researchers, and other stakeholders with involvement in UIC, should be selected.

4. **Information gathering.** In this step, the assessment team selects the instruments for information gathering, and uses them to gather the quantitative and qualitative information identified in step 2 from the participants identified in step 3. The instruments for information gathering include public sources, interviews, and surveys.

    The semi-structured interview/survey approach including open-ended questions and Likert-scale questions structured around the KPAs within UICMM seems appropriate to gather the required information in an unbiased way as open-ended questions can seek an evidence-based response. The benefits of semi-structured interviews have been described in section 4.3.4.3. Semi-structured

in-depth interviews can be conducted face-to-face or by telephone with the responses being recorded digitally as well as in writing. The survey can be conducted electronically. A sample survey questionnaire is provided in Appendix G. It includes questions to gather qualitative as well as quantitative information. The survey will be iteratively improved through use in practice.

A high-level understanding of the UIC maturity level of an organisation can be gained from public sources. Such sources can provide evidence for engagement of an organisation in UICs, the kind of UIC projects it is involved in, and the duration of such engagements. However, other required information is available only within the organisation such as organisational practices, individual practices, and legal practices. Interviews and surveys provide a means to gather such information, including access to confidential information. This specific information will be mapped to the characteristics of KPAs at various maturity levels to understand the achieved characteristics and improvements in the KPAs.

5. **Data analysis.** The data gathered in the above step is analysed in order to understand the UIC maturity level of an organisation.

   Due to the design of the survey questionnaire, responses to the questions can be mapped to the characteristics of the KPAs in the UICMM. However, there is a possibility that responses may be worded in such a way that efforts are required to interpret them. Similarly, data gathered from public sources will need analysis for mapping.

   Content analysis can be applied to analyse the gathered data. Content analysis is 'a research technique for making replicative and valid inferences from texts (or other meaningful matter) to the contexts' [Krippendorff, 2018, pg. 25]. The process of coding [Corbin and Strauss, 1990] can be applied using the deductive approach (Section 3.4) for such analysis of the gathered qualitative data so that the responses can be mapped to the KPA characteristics.

   Further, inferences drawn from analysis of data in the public domain can be validated using data gathered through interviews/surveys. In addition, analysis can be conducted by more than one expert concurrently or in multiple iterations to ensure the reliability and validity of the analysis, and reduce any potential bias arising out of the researchers' background.

6. **Assess organisation.** Based on the analysis in the previous step, an organisation is assessed by mapping the data to the UICMM KPA characteristics and determining the maturity level of the organisation. An organisation achieves a

level of maturity by satisfying all of the characteristics of KPAs at that maturity level and all lower levels. The results of the assessment also provide details of required improvements to the organisation. For example, if an organisation is at maturity level 3, the characteristics at level 4 can be used to identify required improvements.

8.6 Evaluation of the UICMM

As discussed in Section 8.4.1.3, evaluation is a key component of the Design Science Research approach used to develop the UICMM [Becker et al., 2009]. Maturity models can be evaluated in multiple ways with respect to their design process, the design itself, utility, and their practical application. Based on a systematic study of evaluation and assessment of maturity models, three types of evaluations have been suggested [Helgesson et al., 2012]: Author evaluation, Domain expert evaluation, and Practical setting evaluation.

In this section, I describe details of the evaluation process (Requirement R3 of Becker's approach) as well as preliminary results. The evaluation process aligns with the two-phase evaluation approach adopted in this thesis, as described in Chapter 3. Phase one, involves descriptive evaluation, including illustrative scenarios and expert evaluation. Phase two, involving real-world evaluation of the UICMM, is part of the future work, as detailed in Chapter 10.

By combining the Helgesson's [Helgesson et al., 2012] suggestions and the two-phase evaluation, the following approaches have been adopted for evaluation of the UICMM.

- **Author evaluation:** This is an evaluation of the UICMM design and design process without involving outside experts. It was conducted by the researcher, and is presented in Section 8.6.1.

- **Domain expert evaluation:** This is an evaluation of the utility and applicability of the UICMM. It was conducted by involving practitioners, who are potential users of the maturity model or expert in UIC, and is presented in Section 8.6.2.

- **Illustrative scenarios:** This is an evaluation of the utility and applicability of the UICMM by applying it in synthetic situations. It was conducted by the researcher. Section 9.3 in Chapter 9 presents the scenarios that demonstrate use of the UICMM in synthetic situations.

- **Practical setting evaluation:** This is an evaluation of the UICMM through application in real-world settings. I propose a strategy for such an evaluation in

Chapter 10.

8.6.1 Author evaluation: Evaluation of the Design of the UICMM

Becker [Becker et al., 2009] describes a set of requirements that need to be satisfied by the process used to design a maturity model. Section 8.4.1 shows that these requirements were met during the design of the UICMM.

Reviewed literature describes the required properties of a well-designed maturity model [Fraser et al., 2002; Klimko, 2001]. The UICMM design was evaluated against these properties. The result of this evaluation was that the UICMM has all of the required properties as summarized in Table 8.10.

Table 8.10: Evaluation of the UICMM Design

Required Properties	UICMM Properties
i) The way in which maturity of a single domain develops is described in terms of maturity levels (usually four to six).	The domain of interest is UIC. The UICMM comprises five maturity levels to describe the way in which UIC maturity develops.
ii) Levels are characterized by certain requirements	Collaboration levels are characterized with requirements based on Key Process Areas (Section 8.4.3).
iii) Levels are cumulative where higher levels are built on top of the requirements of lower ones	To achieve a level, the UICMM expects that the requirements of the level and all the lower levels 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	UICMM has five distinct and ordered maturity levels, from level 1 to level 5.
v) There is a logical progression through levels and no levels can be skipped	Organisations are expected to progress through levels 1 to 5 of the UICMM. None of the levels can be 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 (Non-existent, Initial, Encouraged, Practised and Managed, and Continuous Improvement) that indicates the intent of the level.
vii) Level definitions should be developed to expand their names and provide a summary of the major requirements and measures	Levels definitions are in a clear state (Table 8.4) and the requirements of each level are defined (Tables 8.5, 8.6, 8.7, 8.8, and 8.9).

8.6.2 Domain expert evaluation: Evaluation for Utility and Applicability of UICMM

In order to assess the utility and applicability of UICMM, the researcher decided to engage and conduct discussions with professionals from organisations interested in UIC. The organisations were selected on the basis of the following criteria:

- The organisation is interested in encouraging UIC.
- The organisation is actively taking measures to improve UIC.

- The participant(s) from the organisation possesses knowledge of UIC and/or maturity models.
- The organisation is interested in practical application of UICMM.

The following organisations were identified as domain experts for this evaluation. These organisations satisfy the above criteria and were selected when they expressed an interest in the UICMM after reading a published paper on the work [Awasthy et al., 2018].

- The Australian Academy of Technology and Engineering (ATSE) [ATSE], and
- Coalfacer [Coalfacer, 2019].

Multiple discussions were held with participants from both the organisations by telephone and video conferencing. Both organisations have shown interest in application of the UICMM, and have provided valuable feedback during discussions. They have expressed satisfaction with the KPAs included within the UICMM. In terms of utility and applicability, the UICMM has been rated highly by the organisations as indicated in correspondence reproduced in Appendix F.

8.7 Conclusion

In this chapter, the UICMM, a maturity model for University-Industry Collaboration, is presented. It is a comprehensive model for assessing and guiding improvement in UICs at the organisational level.

The UICMM was developed by following the maturity model design process proposed by Becker et al. [Becker et al., 2009] and based on design science guidelines [Hevner et al., 2004]. As part of the design, several Key Process Areas, and five levels of maturity were identified. In developing the content of the maturity model, I utilized the UIC Practices Framework presented in Chapter 7, and insights from existing relevant maturity models.

The chapter provides details of the process of application of the UICMM so that it can be used effectively.

The UICMM has been evaluated for its utility and applicability using a descriptive evaluation comprising author evaluation, and domain expert evaluation. Evaluation using illustrative scenarios is presented in Chapter 9. Future work will include ongoing real-world evaluation and improvement of the UICMM in the context of various organisations involved in different types of collaborations as outlined in Chapter 10.