Chapter 7

Discussion & Conclusions
The research objective of this thesis (as stated in Section 1.3) was to present, apply, and develop the TALL modelling approach for human collaboration processes (HCPs), and to evaluate its effectiveness and practical utility in real-life business settings. In the previous chapters, the theoretical and practical results to achieve this research objective have been presented. The approach consists of the following developed components and their supporting software tools:

1. The TALL modelling language and the *Visual Editor* (all chapters);
2. The design-time verification method and *TALL2HCPN* (Chapter 2);
3. The global construction algorithm and *Local IS Integrator* (Chapter 3);
4. The e-mail interaction mining method and *E-mail Interaction Miner* (Chapter 4);
5. The two-phase modelling method for local agent behaviour specification and analysis within a HCP’s interactions (Chapter 5);
6. The multi-view interaction modelling method and *Local IS Integrator* (Chapter 6);
7. The set of TALL modelling guidelines: a list of modelling activities that relates the language and methods above in order to support modellers in the usage and application of the approach (this chapter).

The corresponding chapters presented and applied these artefacts. All the method artefacts (i.e. list items 2 to 7) utilize the TALL modelling language for the graphical description of HCPs.

In Section 7.1, this chapter reflects on the three evaluation case studies in Chapter 4, Chapter 5, and Chapter 6 with a cross-case analysis. Based on this analysis, several scientific statements about the TALL modelling approach are made. After, Section 7.2 presents the set of TALL modelling guidelines. Finally, Section 7.3 concludes this thesis with a discussion of the main research contributions and possible directions for future research.

### 7.1. Cross-Case Analysis

The focus in the three evaluation case studies was primarily at demonstrating the situated utility of the TALL modelling approach in the local business context of the particular cases. This orientation is consistent with the adopted research methodology that integrates case study research and design science research (see Section 1.5), which both have an applied orientation. The knowledge generated in individual cases can be generalized based on reflection and cross-case analyses.
(van Aken, 2004). A cross-case analysis is theory-oriented in the sense that (evaluation) results from multiple cases are analysed to contribute to the robustness and generalizability of a theoretical statement or explanation (Dul & Hak, 2008). Based on a cross-case analysis of the three evaluation case studies, this thesis makes the following scientific statements.

**Statement 1:** The TALL modelling approach allows effective identification and modelling of HCPs in organizations (condition X), which enables valuable analysis (effect Y).

This statement expresses a sufficient condition: “if there is X then there is Y”. The three evaluation case studies show that the TALL modelling approach successfully and effectively models the three selected HCPs (i.e. condition X is present in each case). Furthermore, the approach generates actionable managerial insights in the form of HCP improvement opportunities after analysis of the TALL diagrams (i.e. effect Y is present in each case). This proves the practical utility of the approach and provides evidence that the statement is correct. However, since the statement expresses a sufficient (but not a necessary) condition, effect Y can have other causes or conditions (even if the statement is true). Moreover, future empirical evidence may reveal that effect Y does not always occur, which would contradict the statement. Thus, the evaluation results corroborate (but not prove) that condition X is a sufficient cause for effect Y. Nevertheless, the support found for the statement in three separate case studies enhances the degree of confidence that the statement is correct and applies to the entire theoretical domain.

The theoretical domain is the universe of instances of the object of study for which the statement is believed to be true (Dul & Hak, 2008). From this domain, specific cases are selected. In this thesis, the theoretical domain is formed by HCPs in organizations. The main object of study is human interactions in HCPs. For practical reasons (i.e. ease of access, time and resource constraints), the cases were selected from a geographically bounded subdomain, that is, HCPs in Dutch organizations. As mentioned in Section 1.5.1, an exploration of practice was performed in the initial phases of each case study. The goal of this exploration was to confirm the relevance of the case for this research. The main case selection criterion was the existence of (organizational) problems related to human interaction structures. In each of the three evaluation case studies, the human interaction structure in a specific business activity was not properly defined, which
inhibited proper HCP management, analysis, and improvement. The result was the selection of HCPs in three different sectors:

- Private Sector: evaluation case study at Gasunie Transport Services Inc. (Chapter 4);
- Public Sector: evaluation case study at the Municipality of Oldambt (Chapter 5);
- Healthcare Sector: evaluation case study at the University Medical Center Groningen (Chapter 6).

In selecting these cases, no defined selection criteria in terms of the type (e.g. synchronous/asynchronous, verbal/non-verbal, physical/virtual), form (e.g. discussion, conversation, consultation), or scope (intra-/inter-organizational) of human interactions were used. As a result, the interactions modelled within the three cases are very diverse. The advantage of the diversity in interactions is that the TALL modelling approach has been applied to identify and model a large number of human interactions, which enabled proper testing of its abilities. The TALL Interaction Structure (IS) diagrams in each of the cases contain a mix of interaction types and forms, in many cases with participants from different organizations. An exception, in terms of the diversity of interaction types and forms, is the evaluation case study in Chapter 4 in which all modelled interactions are e-mail interactions. Thus, in this case study, all interactions are asynchronous conversations. In the other evaluation case studies, the diversity in interactions is the result of the relatively broad definition of human interaction. According to the definition provided in Section 1.2, any reciprocal business act between two or more roles that is directed towards a common goal or benefit is an interaction. Future research intends to define more clearly what can and cannot be considered a human interaction (see Section 7.3.2).

**Statement 2:** The TALL modelling approach can be useful to identify, model, analyse, and improve HCPs in other organizations as well - this research topic deserves further scientific and practical investigation.

The positive evaluation results in the three cases from three different sectors prove that organizational problems related to HCPs are not constrained to specific business domains and are likely to exist in other organizations as well. Multiple cases clarify that a finding or phenomenon is not idiosyncratic to a single case (Eisenhardt, 2007). Therefore, it is reasonable to expect that the interaction-centric
TALL modelling approach can be useful to identify, model, analyse, and improve HCPs in other organizations as well. In general, the positive experiences and findings obtained in the three evaluation case studies confirm that this research topic deserves further scientific and practical investigation. New applications of the approach, including comparative studies with workflow-based process modelling approaches, are planned for the future (see Section 7.3.2).

Statement 3: The core component of the TALL modelling approach (i.e. the TALL modelling language) is well suited for the graphical description of HCPs.

The TALL modelling language has the following strengths.

1. The language is effective
The language proved well suited to describe the interaction structures of the target HCPs in the three evaluation case studies. In particular, the tree layout of the IS diagram proved a powerful concept to model and understand the many interaction interrelations (i.e. routing and composition relations). The interaction-centricity of the language allowed the modeller to focus on the essential interactions that contribute to the execution of the target HCP without being concerned with the details of the behaviours of individual agents. In a second modelling phase, the IS diagram proved an effective anchor for the individual behaviour specification in Agent Behaviour (AB) diagrams (see Chapter 5). Overall, the language separates between two levels of ‘linked’ process flows. The macroflow of interactions in the IS diagram allows to specify “what” to perform in terms of collaborative multi-agent activities. The microflow of behaviours in the associated AB diagrams allows to specify “how” to perform these in terms of individual single agent activities. Despite the conceptual separation, the process modelling is completely hierarchical. Interactions can be specified in more detail using (child) interactions or using agent behaviours on the elementary level. This divide-and-conquer approach proved effective in real-life to tackle the complexity of HCPs.

2. The language is agent-oriented
The agent-oriented concepts, on which the language is based, fit the collaborative nature of HCPs. The graphical syntax and diagrams allowed to model the essential components of the three target HCPs: role-based multi-agent interactions in the IS diagram, and agent behaviours in the AB diagram. Moreover, the language allowed
to model the static aspects of the organizational environment of each target HCPs with the TALL Agent Structure (AS) and Role Structure (RS) diagrams. This makes TALL a business process modelling language instead of a process modelling language (Barjis, 2007).

3. The language is rigorous
A well-defined formal semantics supports the graphical syntax. This makes the language more than a diagrammatic convention and enables formal analysis (i.e. implementation in Petri nets and structural model checking as demonstrated in Chapter 2). Moreover, as Chapter 2 indicates, the formal TALL diagrams can be executed by a simulation environment to develop software agents for HCP support. In a next phase of a HCP’s lifecycle, the models can reside in a deployed multi-agent system and be executed for real-life HCP support.

4. The language is robust
The positive evaluation results in the three evaluation case studies from three different sectors proves that TALL’s modelling constructs are not specific to a certain business environment. This strengthens language robustness and generalizability.

5. The language produces accurate descriptions of reality and is useful in practice
The face validation sessions, organized in the three evaluation case studies with key people from the target organizations, demonstrated that the language correctly models real-life HCPs and meets user expectations. The graphical syntax shields business users from the formal semantics. Therefore, the business people (i.e. process owners) who will actually manage and/or improve a HCP can relate to and understand the TALL diagrams. The evaluation results prove that the language is a valuable asset for HCP identification, modelling, analysis, and improvement. A long-term goal is to achieve more widespread use of the language by for instance business analysts. This is part of future work (see Section 7.3.2).

7.2. TALL Modelling Guidelines
Based on the modelling experience obtained in the four case studies in Chapter 2, Chapter 4, Chapter 5, and Chapter 6, the following list of modelling activities supports modellers in the usage and application of the TALL modelling approach and its components.
1. Build an Agent Structure Diagram
The (lead) modeller creates an AS diagram of the business environment under consideration to scope the organizational population. The case applications in Chapter 2 (see Figure 2-2) and Chapter 6 (see Figure 6-3) included the creation of an AS diagram. The evaluation case study in Chapter 6 used the AS diagram to create a graphical representation of the organizational structure under consideration with involved business units, departments, and department centres. The diagram was then used to identify human agents within these synthetic agents to obtain a representative group of healthcare workers for the interviews. Thus, in Chapter 6, the AS diagram facilitated the selection of the interviewees. In general, the identification and modelling of the agent structure in the business domain under consideration is the primary purpose and value of the AS diagram. Besides synthetic and human agents, the illustrative case study in Chapter 2 showed that the diagram also allows the modelling of software agents (e.g. legacy systems). This enables the capture and understanding of the (structure of the) information technology (IT) landscape.

2. Build a Global Interaction Structure Diagram
The modeller(s) create(s) a global IS diagram of the interactions in the target HCP.

Single view situation
In this situation, the modeller creates the global IS diagram in a top-down way either in a model-based workshop or based on an interaction log. In a model-based workshop, models are built interactively with subject matter experts who talk about the process and a modeller who changes the models on the fly (Bridgeland & Zahavi, 2009). A model-based workshop reflects a single view situation because the local interaction views of the participants are not explicitly modelled in local IS diagrams as in the multi-view situation (see below). Instead, the human input is directly processed in the global IS diagram by the (lead) modeller during the workshop. In Chapter 5, the global IS diagram was completed and validated in a model-based workshop in which all process participants sat together.

A model-based workshop is recommended for relatively small HCPs, like in the Chapter 5 case study, which are performed in a single organizational unit with a small group of participants. In this case, a model-based workshop is efficient because of the speed of the modelling process (i.e. no interviews are required to
create the global IS diagram). A model-based workshop may also be required when
the business domain under consideration cannot or is not willing to commit their
employees to the interviews required in the multi-view situation (i.e. because of
time or resource constraints).

For large-scale HCPs with many distributed participants, like in the Chapter 6
case study, the model-based workshop approach has disadvantages. First, with a
large group of participants it is difficult to obtain everyone’s input. The group
setting of a workshop may intimidate some participants, who may be afraid to
speak up and voice an own opinion (Buelens, van den Broeck, Vanderheyden, &
Kinicki, 2006). On the other hand, if only a few (key) participants attend the
workshop, valuable tacit domain knowledge is not collected. Second, the model-
based workshop approach does not work in distributed settings where (some of) the
participants cannot sit together or are not willing to sit together. In the Chapter 6
case study, because of their local views, healthcare workers did not have a good
understanding of the overall healthcare HCP. Therefore, they found it hard to
discuss and agree with colleagues from other disciplines and departments on the
interactions to be represented in the global IS diagram.

If there is an organization where an e-mail archive or log is available to discover
and represent an email-driven HCP, the Email Interaction Mining (EIM) method
from Chapter 4 can be selected and applied. The EIM method builds the global IS
diagram directly from the interaction log (i.e. in a top-down way). An interesting
avenue for future research is to improve the developed interaction mining tool to be
able to discover an IS diagram from other interaction logs (see Section 7.3.2).

**Multi-view situation**

In this situation, the modeller applies the Multi-View Interaction Modelling
(MVIM) method from Chapter 6 to collect and formalize the tacit domain
knowledge of the human process participants in local IS diagrams. In other words,
the local interactions views of the participants are explicitly modelled. Next, the
(lead) modeller can automatically integrate the created local IS diagrams into a
global IS diagram using the software implementation of the MVIM method. In this
way, the global IS diagram is created in a bottom-up way. The local IS diagrams
that serve as input to the method can be created separately and concurrently by
multiple modellers. In the Chapter 6 case study, two modellers used interviews to
collect and formalize the tacit domain knowledge of the selected healthcare
workers.
The MVIM method is recommended for large-scale distributed HCPs where the process participants are concerned with different aspects of the target HCP and/or are involved in different phases of the target HCP (or when the process participants cannot or are not willing to sit together as mentioned under the single view situation). Usually, this is the case when the diversity of the process participants in terms of their professional backgrounds and functional areas of expertise is great. The advantage of the MVIM method for such HCPs is the use of one-to-one focused interviews, which allows the tacit domain knowledge of the human process participants to be collected and formalized in cooperation with the interviewee. This benefits the completeness and accuracy of the TALL diagrams. In turn, this benefits the usefulness of the diagrams for process analysis and improvement purposes. Another advantage of the MVIM method for large-scale HCPs, as described above, is the inherent support for a multiple modeller situation.

Both the single view situation (i.e. model-based workshop) and multi-view situation (i.e. MVIM method) can benefit from a preliminary high-level IS diagram, created based on organizational documentation. In Chapter 5, a preliminary high-level IS diagram facilitated the execution of the model-based workshop. In Chapter 6, a high-level preliminary IS diagram served as input to the one-to-one interviews to provide a generic starting point for the creation of the local IS diagrams. In business domains where the organization(s) does(do) not want to commit human resources at all, the global IS diagram can be created based on organizational documentation only.

3. Build a Role Structure Diagram
The (lead) modeller can create a RS diagram of the unique roles in the global IS diagram. A RS diagram accompanies a global IS diagram and can be created for several purposes. First, it can graphically depict and explain to which organization (or organizational unit) a role in the global IS diagram belongs. In the Chapter 4 case study, company suffixes were added to the roles in the global IS diagram to distinguish between the roles of different companies (see Figure 4-10). Alternatively, an RS diagram could have been created to provide this information. Second, a RS diagram can explain possible role grouping in the global IS diagram. Role grouping provides for clean IS diagrams by avoiding role clutter as parent interactions collect the roles of their children in a bottom-up way. The Chapter 2 case study created an RS diagram for this purpose (see Figure 2-5) to accompany
the global IS diagram (see Figure 2-3). Third, in general, an RS diagram may be used to depict a reporting structure within a single organization (i.e. chain of command). Finally, RS diagrams may be used to define authorization schemes. In this context, role building may be used to design agent groups, which are generic sets of agents with similar skills. For this, roles have to define permissions (i.e. constraints) to make sure only agents, who are members of a certain agent group, are authorized to play that role. This research avenue was also mentioned in the future work of Chapter 2 (see Section 2.9).

4. Perform Interaction Analysis
The (lead) modeller performs analysis of the global IS diagram, possibly in cooperation or consultation with (key) people from the business domain under consideration, to identify HCP improvement opportunities. The evaluation case studies in Chapter 4, Chapter 5, and Chapter 6 each present several improvement opportunities with regard to the target HCP’s interaction structure after (qualitative) process analyses of the created global IS diagrams.

5. Build Agent Behaviour Diagrams
The global IS diagram provides a good starting point for the specification of the individual local agent behaviours. The elementary interactions in the IS diagram (i.e. the leafs in the interaction tree) are completed by the coordinated execution of the behaviours of the agents playing the roles. For each elementary interaction, the modeller(s) can collect knowledge about the agent behaviours and formalize this knowledge in AB diagrams. In most cases, this knowledge is collected through (another round of) interviews, like in Chapter 5. Alternatively, the modeller may pursue other data collection methods like desk study of organizational documentation (e.g. protocols, procedures, norms), non-intervening observation, or key informant consultations. The goal of this modelling activity is to inform the sixth activity Perform Behaviour Analysis (see below). In the Chapter 2 case study, the modelling of the behaviours of legacy IT systems (i.e. software agents) in terms of generic system activities (read: functionalities) was also illustrated. This allows to investigate interaction touch points with other agents (e.g. how a human interacts with an IT system as part of a HCP).
6. Perform Behaviour Analysis
The modeller(s) analyse(s) and/or compare(s) the AB diagrams to reap business value from them. This thesis demonstrated two types of behaviour analysis:

- Qualitative Behaviour Analysis: in Chapter 5, the modeller (cross-) analysed the AB diagrams to identify deficiencies and/or innovations within and across local behaviours. This resulted in several actionable managerial insights for the case organization on the behaviour level;
- Verification Analysis: in Chapter 2, the modeller used the design-time verification method to translate the global IS diagram and the associated AB diagrams to a hierarchical coloured Petri net to enable verification analysis. This resulted in several valuable observations on the structural correctness and compatibility of the individual agent behaviours that complete a certain elementary interaction. After correction of the identified errors, this resulted in improved AB diagrams. The verification analysis may be performed after a redesign of agent behaviours based on a qualitative behaviour analysis. In this way, the structural correctness and compatibility of (redesigned) agent behaviours can be analysed before they are used for further design and/or implementation. For instance, such behaviours may be used to directly code the behaviours of software agents in a multi-agent system for real-life HCP support.

7.3. Conclusions

7.3.1. Research contributions
This thesis has undertaken empirical design research to present, apply, develop, and evaluate a novel graphical business process modelling approach named TALL. The approach allows for the identification, modelling, analysis and improvement of Human Collaboration Processes (HCPs). A HCP consists of a process structure of related interactions (e.g. meetings, conversations, consultations, discussions) between agents, who may each play different roles. The following summarizes the motivation behind and innovation of the approach.

In Business Process Management (BPM) research and practice, the study of workflow processes is widespread. These studies are mostly technology-oriented with a focus on the implementation of workflow processes in workflow management systems (Houy, Fettke, & Loos, 2010). Workflow management systems allow organizations to streamline and automate business processes, re-engineer their structure, as well as, increase efficiency and reduce costs (Cardoso,
Sheth, & Miller, 2002). These systems use a workflow model to control the execution of the tasks in the process. In this way, the system provides automated process support. Therefore, a workflow model specifies which tasks in a process need to be executed and in what order (van der Aalst, 1998). Workflow modelling is mostly done using graphical process modelling languages. The essence of these languages is similar; they create flowchart or graph-based models in which the collection of tasks and their ordering relations are formalized in task execution sequence (Wang & Wang, 2006). Overall, the huge focus and investment in the study of workflow processes and their Information Technology (IT) support has produced proven modelling tools.

In HCPs, collaboration instead of task sequence determines the nature of the business activity (Harrison-Broninski, 2005). This thesis argues that pervasive graphical workflow-based process modelling approaches have shortcomings to model those processes that require intensive human interaction for their completion. This is mainly due to their focus on workflow processes, and the definition and automation of workflow processes as task structures. Several authors confirm that existing graphical (workflow-based) process modelling languages are appropriate for modelling business processes that display complex task flows (i.e. workflow processes) but are less appropriate for modelling business processes that involve the interaction of a multitude of actors (i.e. HCPs) (Barjis, 2007; De Backer, Snoeck, Monsieur, Lemahieu, & Dedene, 2009; Hommes, 2004; Melão & Pidd, 2000; Ryu & Yücesan, 2007; Stuit & Wortmann, 2010). With HCPs, the goal of process modelling is not primarily IT support or automation but in the first place to capture and define accurately the essence of collaboration, as a necessary basis for their analysis and improvement.

Although human interactions are adopted in practice as an effective way to collaborate, organizations do not define - let alone manage - them as a business process. This is remarkable since human interactions constitute an essential part of a modern organization’s activities. The net result is that human interaction structures in organizations remain largely implicit; there exists no process definition of human interactions in organizations. Therefore, HCPs are not amenable to proper process design, analysis, and improvement. This is the core of the organizational problem in the case studies performed in this thesis (see below).

The lack of proper modelling tools for human collaboration and interaction was the motivation to develop the interaction-centric TALL modelling approach in order to fill the gap, and provide an effective and useful modelling tool for HCPs in
organizations. The approach is inspired by the agent paradigm. As indicated above, most pervasive process modelling approaches are inspired by the workflow paradigm (Fischer, 1995). Using the TALL modelling approach, an organization is viewed as a multi-agent environment in which different agents behave in role-based interactions to coordinate their work. This is a paradigm shift in BPM research and practice. In the approach, the main modelling concept is the interaction (performed by multiple actors) instead of the task (performed by a single actor). The interaction-centricity results from the agent-orientation (i.e. agent interactions stand central in multi-agent systems research). The power of the agent-orientation is that it provides rich graphical notations to model a HCP’s human interaction structure (i.e. interactions, their composition and routing relations, their roles, and their participants or agents) and the behaviours of the agents that are used to perform the interactions. Moreover, the agent-orientation provides explicit support for the modelling of local individual process views on both the interaction and behaviour level. In this regard, TALL offers an internal observer view (i.e. an agent-centric perspective). This is opposed to the external observer view of most existing process modelling approaches.

Other modelling approaches have emerged that adhere to different paradigms to capture those business processes that are collaborative of nature. For example, modelling approaches that adhere to a social paradigm conceive business processes as a special kind of social interaction process (Wagner, 2003), as patterns of interaction and action (Dietz, 2006), as social constructs (Melão & Pidd, 2000), or as a holarchy of human activity systems (Clegg & Shaw, 2008). Other examples are the case handling paradigm (van der Aalst & Weske, 2005) and the rule-based paradigm (Goedertier, Haesen, & Vanthienen, 2008), which both aim to make process definition and enactment more flexible. The emergence of these modelling approaches confirms that (1) modern business processes are more complicated than the scope and features of pervasive workflow-based process modelling tools, and (2) there is a need for HCP-like process investigation and support tools.

The research methodology applied in this thesis integrates case study research and design science research. The adopted design science research framework is shown in Figure 7-1 and includes activities for problem identification (i.e. the research motivation), developing the artefact, evaluating the artefact, and demonstrating research contributions. As discussed above, the research process draws from foundations in the existing knowledge base of the BPM field to motivate the development of the TALL modelling approach. Moreover, multi-
agent systems research provides theoretical concepts that led to the main language concepts: interactions, behaviours, agents, and roles. Furthermore, the research process makes use of sound methodologies (i.e. case studies) available in the knowledge base for the development and evaluation of the approach. Case studies allowed the development of the TALL modelling approach in close interaction with reality while at the same time the practical utility of the approach to solve identified organizational problems could be evaluated. A single case study (Chapter 2) and an illustrative process example (Chapter 3) was used to present the initial design of the approach, and a multiple case study consisting of three evaluation case studies (Chapter 4, Chapter 5, and Chapter 6) was used to demonstrate the utility of the approach in real-life HCP (re)design situations.

Figure 7-1. The design science research framework adopted in this thesis. Based on (Hevner, March, Park, & Ram, 2004; Vaishnavi & Kuechler Jr., 2008).

The main theoretical (design) contribution of this thesis is the TALL modelling approach, which proved useful and effective in practice. The close connection with reality produced an approach that has high validity with the people in the field and that can address practical business problems. In each evaluation case study, the application of the approach had a strong observable effect in solving the organizational problem. More specifically, in each case, the approach defined the (previously implicit) target HCP’s interaction structure, which enabled proper process analysis and improvement. Several actionable managerial insights in the
form of HCP improvement opportunities were identified in each evaluation case study. Based on this, the main practical contribution of this thesis is the business value realized in each evaluation case study. As Figure 7-1 shows, the theoretical contribution is added to the existing knowledge base, and the practical contribution flows back to the business environment in which the (organizational) problem was identified. According to Hevner, March, Park, and Ram (2004), the contributions of design science are assessed as they are applied to the business needs in an appropriate environment (i.e. practical contribution) and as they add to the content of the knowledge base for further research and practice (i.e. theoretical contribution).

Each process modelling approach has certain strengths, fits certain purposes, or adheres to certain theoretical perspectives. There is no general-purpose process modelling tool suitable for all projects in the BPM field (Bider, 2005). The outcomes of this research strongly suggest that the TALL modelling approach has potential within the BPM community. In this regard, the approach may serve as a valuable addition to the assortment of existing process modelling approaches. This thesis showed how the approach can identify HCPs in organizations, provides powerful concepts to model agent interaction and behaviour, and contributes to the understanding and improvement of the target HCP. Overall, the evidence suggests that HCPs in organizations can be effectively identified, modelled, analysed, and improved via the interaction-centric TALL business process modelling approach. Clearly, the approach is not finished. Section 7.3.2 presents possible future research directions.

Besides the main theoretical contribution in the form of the TALL modelling approach, the chapters in this thesis provide the following specific theoretical contributions:

- The main innovation of the TALL modelling approach, when compared to existing agent-oriented modelling approaches in multi-agent systems research, is its focus on business process specification instead of system specification (Chapter 2 of this thesis);
- The design-time verification method allows to verify the structural correctness and compatibility of the individual agent behaviours that complete a certain elementary interaction. The design-time verification method is different from other verification methods due to its ability to trace back identified design errors to individual agent behaviours. In a broader context, this enhances the reliability and quality of the TALL Agent
Behaviour (AB) diagrams, which may be used as requirements in the development of software agents for intelligent IT support of humans in their workplace interactions. For example, the verified AB diagrams may serve as executable specifications for software agents (Chapter 2 of this thesis);

- E-mail is one the primary media for business communication and collaboration. The Email Interaction Mining (EIM) method can discover (i.e. reverse-engineer) an e-mail-driven HCP from a historical e-mail archive. The EIM method is different from other process mining methods in the sense that the interaction (i.e. a collaborative activity by multiple actors) instead of the task (i.e. an individual activity by a single actor) is the basic building block to construct the process. The EIM method is different from other e-mail tools because of its focus on BPM instead of individual user management (Chapter 4 of this thesis);

- In existing workflow-based process modelling languages, the graphical representation of interaction structures is weak due to the focus on task specification, which makes the capture of the essence of HCPs difficult. This is named the interaction shortcoming. In the TALL modelling language, interaction specification is done in the Interaction Structure (IS) diagram where interaction is the fundamental process element. The tree layout of the IS diagram breaks the opacity of a HCP and overcomes the interaction shortcoming (Chapter 5 of this thesis);

- In existing workflow-based process modelling languages, the process model prescribes generic process behaviour. This standardizes behaviour and makes process execution efficient. However, such a model does not explicitly define local behaviour and therefore prevents the analysis of local differences in behaviours. This is named the local view shortcoming. In the TALL modelling language, the AB diagrams capture explicitly the local operational process views of the owner agents in a given interaction. This retains local process diversity and overcomes the local view shortcoming (Chapter 5 of this thesis);

- The Multi-View Interaction Modelling (MVIM) method makes use of personal interviews to capture the tacit domain knowledge of human agents and to formalize this knowledge in local IS diagrams. The MVIM method is different from existing methods in the BPM field because of the interaction-centricity, and the explicit capture and modelling of local interaction views. The interviews take the form of mini-workshops between the interviewer
and the interviewee. Each interviewee is actively involved in the creation of the local IS diagram. This setup fuels the interviewee’s involvement and interest, which leads to more precise local IS diagrams. Moreover, it allows for immediate validation of the local IS diagrams (Chapter 6 of this thesis);

- The MVIM method makes use of the global construction algorithm (see Chapter 3) to automatically integrate the created local IS diagrams in a global IS diagram. The algorithm does not streamline (i.e. standardize) the local interaction views of the process participants but consolidates them. The global IS diagram provides an overview of a HCP’s interaction structure, which reflects the consolidated domain knowledge. The integration feature enables effective division of work since multiple modellers can work independently and concurrently on different local IS diagrams, and then provide them as input to the MVIM method (Chapter 6 of this thesis).

### 7.3.2. Future research directions

The previous chapters highlighted future work related to the specific content of the particular chapters. This section provides general directions for future research. The main thrust of future work is concerned with research to strengthen the validation of the TALL modelling approach. Both qualitative and quantitative validation studies are planned.

As qualitative research, future applications of the approach to HCPs in (non-Dutch) organizations are intended to further the (re)design of the approach. These empirical studies are planned to include comparative analyses of TALL and conventional workflow-based process modelling approaches. For instance, a traditional (single-view) process modelling method, making use of e.g. BPMN, can be compared to the MVIM method, making use of TALL. To realize this, two groups of students can study two similar HCPs in two different organizations with one group applying the traditional method and the other group applying the MVIM method. When both studies complete, an evaluation of the advantages and disadvantages of both modelling methods can be performed together with (key) people from the organizations under consideration.

As quantitative research, a comparative laboratory experiment concerned with model validation is planned for the future. A common source of difficulty in conventional (task-centric) process modelling languages is an appropriate visual method to reduce the complexity of large diagrams where users have to model interactions between a wide range of actors (Hommes, 2004). Therefore, a laboratory experiment intends to examine the effectiveness of the interaction-
centric TALL modelling language in comparison with a conventional task-centric process modelling language. Separate experiments can be performed of a HCP and a workflow process to thoroughly investigate the strengths and weaknesses of the languages in modelling both types of business processes. At first, a two-group experimental design can be used. Next, the findings of the first experiments may help to isolate the specific effective notations of both modelling languages and inform more sophisticated experimental designs.

The qualitative and quantitative validation studies described above enable a better understanding of the capabilities, limitations, and appropriateness of the TALL modelling approach. An important part of future validation relates to dissemination. In this regard, the planned action is to establish and maintain a committed research team for the management and evolvement of the approach, and to make the approach more known in both industry and academia. In this way, a larger community of researchers and/or practitioners may perform critical analyses of the approach.

Besides the main thrust of future work that is concerned with validation, specific future research directions are associated to different components of the TALL modelling approach. With regard to the TALL modelling language, the IS diagram currently does not provide distinct language elements to express interaction types (e.g. synchronous/asynchronous, verbal/non-verbal, physical/virtual) and forms (e.g. discussion, conversation, consultation). Both the interaction form and type are implicit from the interaction label or name. Moreover, a formal semantics for the AS and RS diagrams is to be included in the language. This thesis mainly focused on the process diagrams of the language, that is, the IS and AB diagrams. In this regard, the practical utility of the AS and RS diagrams needs to be established, and advanced guidelines for the integrated use of the different TALL diagrams need to be developed. With regard to the set of TALL modelling guidelines, the first extension is to specify more advanced procedures that can assist modellers in the identification of agents, roles, interactions, and behaviours. Furthermore, other data collection methods for the interaction and behaviour capture are to be explored. Currently, the data collection process uses interviews, which is quite laborious, especially for large-scale HCPs when also the agent behaviours are to be identified and formalized in models. With regard to the discovery of HCPs through interaction mining, the goal is to improve and generalize the developed mining tool (see Chapter 4) to work with other interaction logs (e.g. digital user agenda’s, multi-agent system execution logs etc.).
As a next step in the lifecycle of a HCP, future work intends to apply interaction-centric process modelling tools – like the TALL modelling approach – as the first phase in the development of multi-agent systems that support real-life HCPs. This provides many avenues for future research and development.